KAGRA Auxiliary Optics

Tomo Akutsu (NAOJ)

Information session of KAGRA subsystems and research themes for students (27 May 2021)

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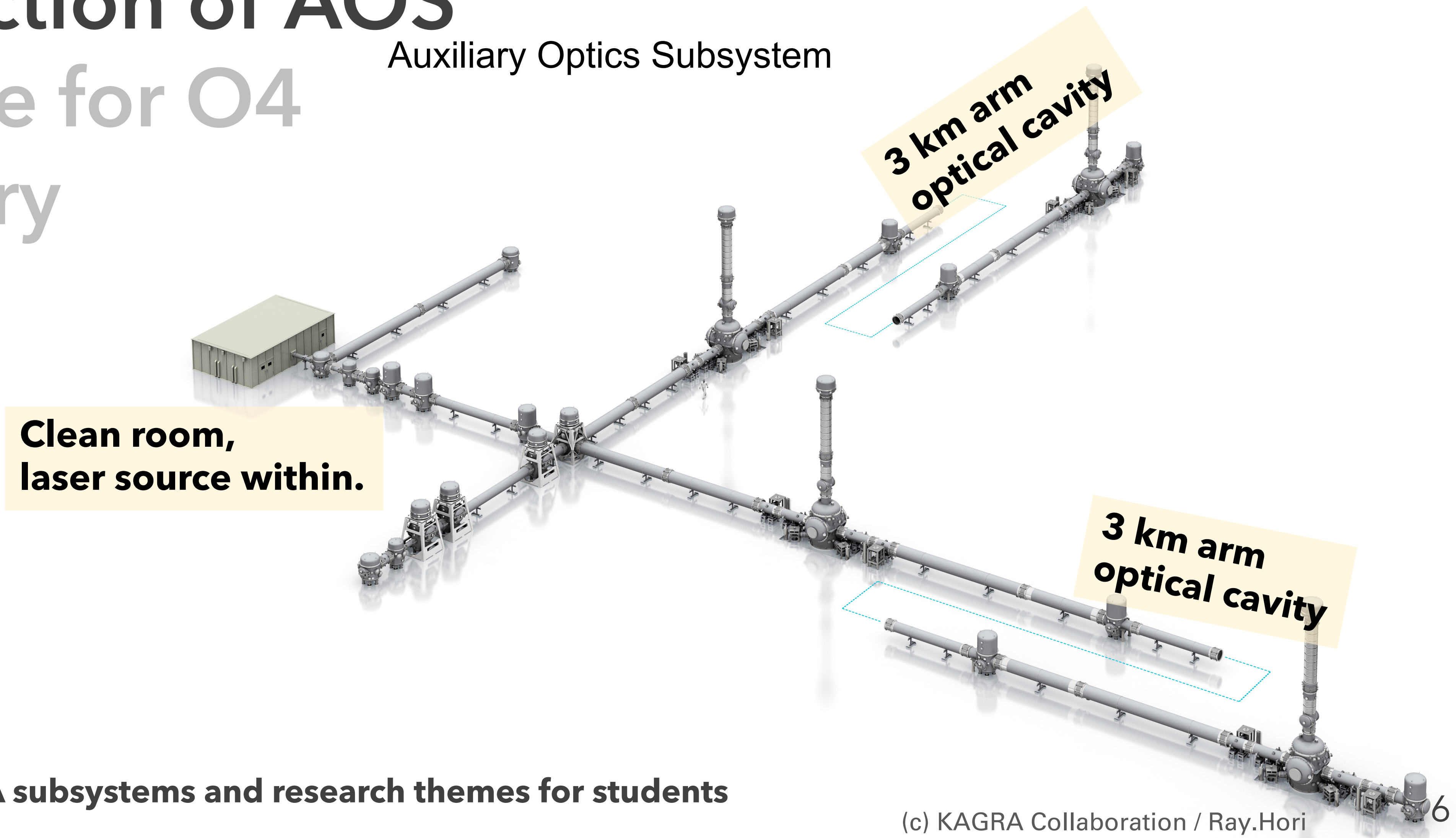
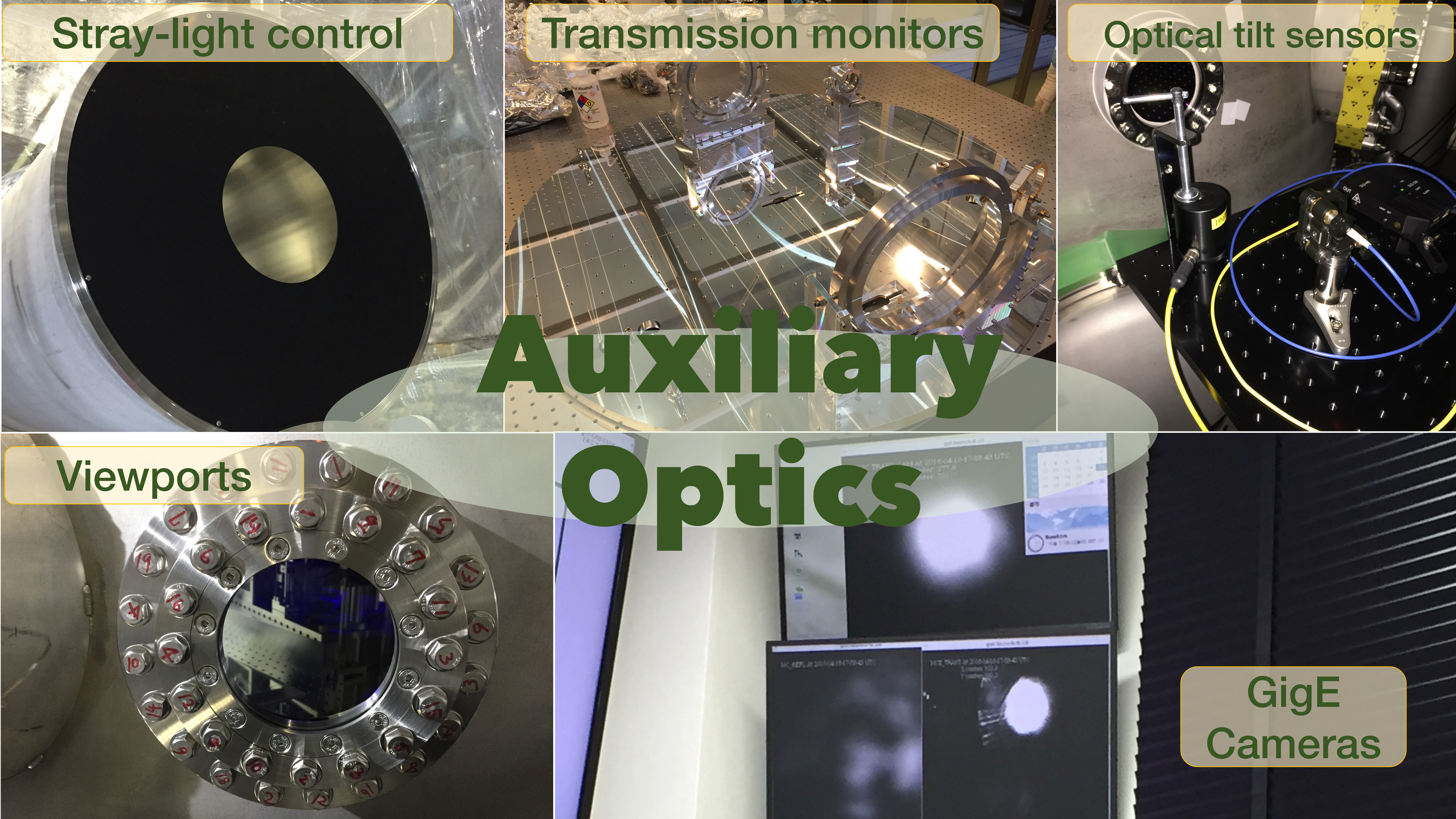
- Upgrade for O4
- Summary




Stray-light control
Transmission monitors
Optical tilt sensors
Auxiliary
Optics
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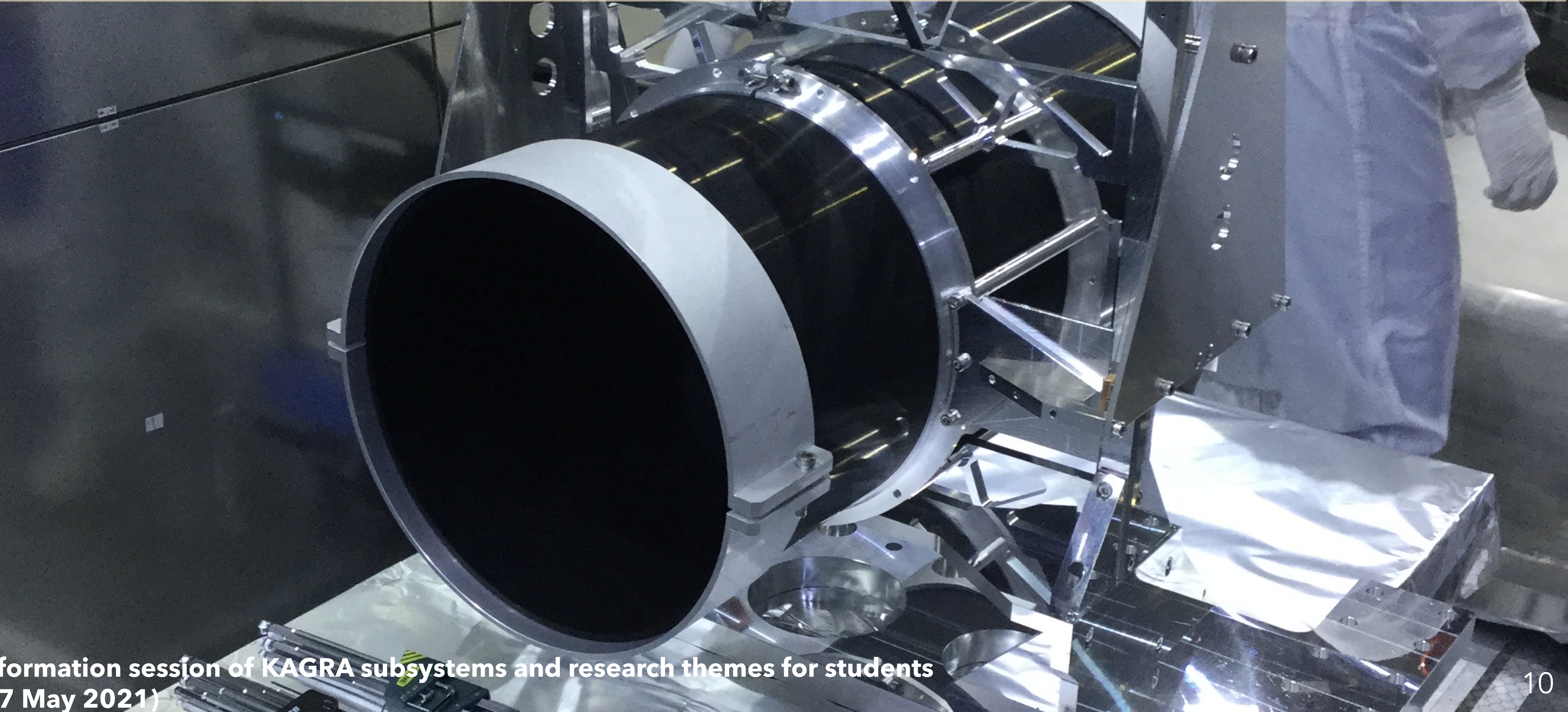
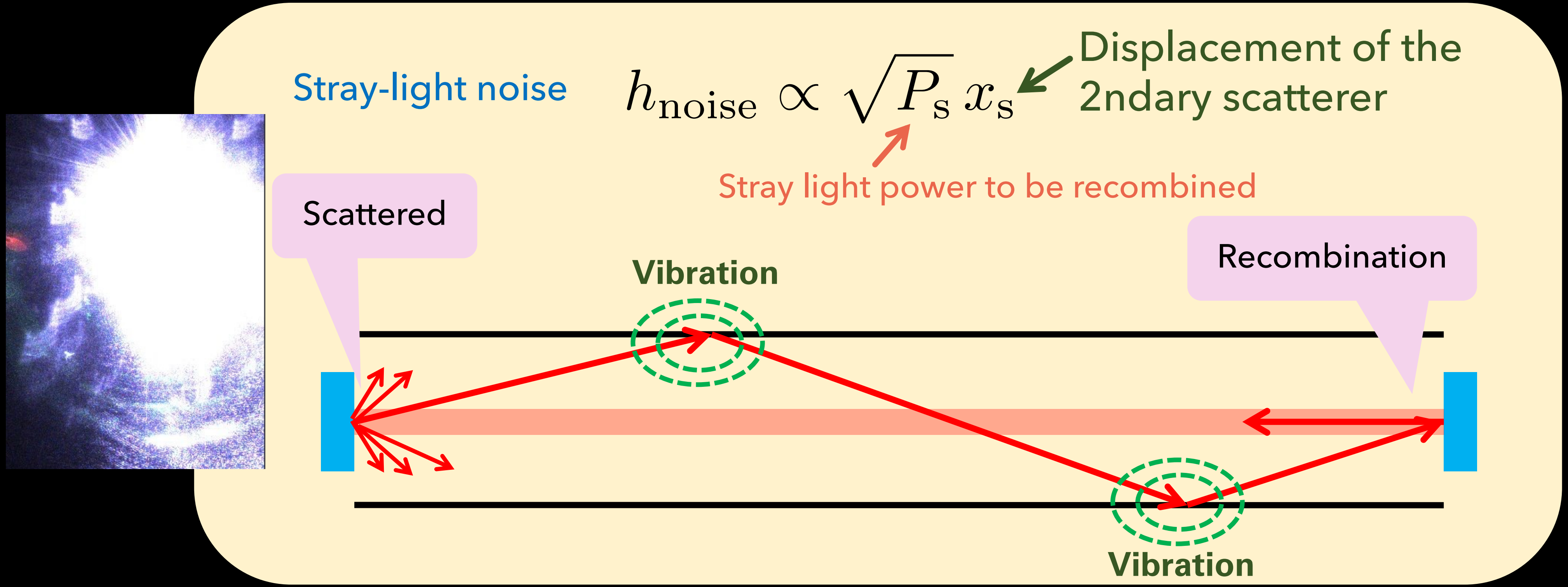
Stray-light control



Stray-light noise

- Practically critical noise
- Hard to predict
- Took long time to reduce it, but…



Develop the stray light simulation method

Possibly estimatable by ray trace simulation

Stray-light noise

$$h(f) = \frac{1}{L} G(f) \sqrt{\frac{\mathcal{P}_0}{\mathcal{P}_{\mathrm{in}}}} \frac{\left(\sqrt{\mathcal{P}_{\mathrm{s}}} \sin \phi_{\mathrm{s}}\right)}{\sqrt{\mathcal{P}_0}}$$

Arm length（3km）

Response of the interferometer:
Simulation with another tools

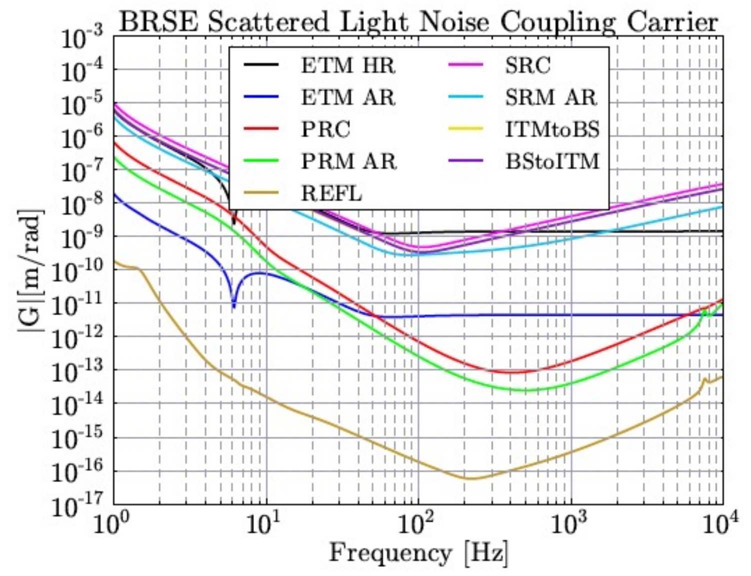
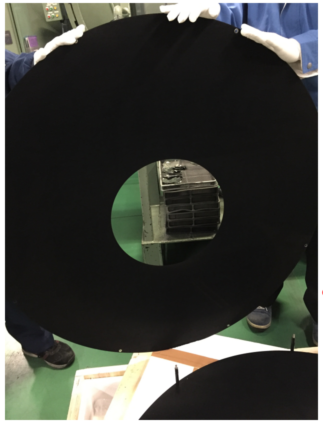


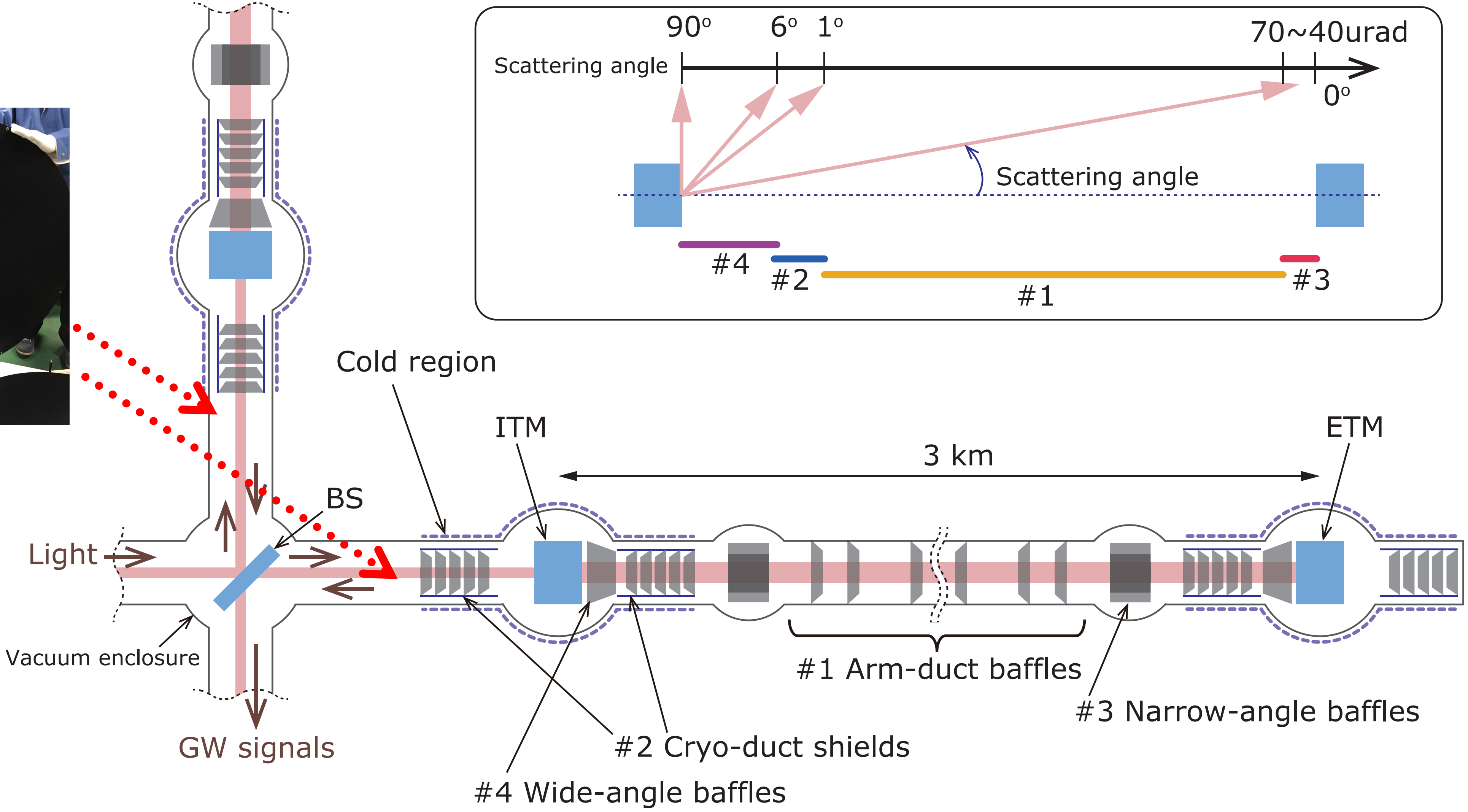
Figure 4.20: Coupling coefficients of scattered light for the carrier: BRSE

Mainly a combination of:

- Ray trace: With off the shelf software (Zemax, LightTools,…), it is hard to simulate photons behaviors accounting interreference of them.
- Response of the interferometer: need another tools.

Stray-light mitigation in KAGRA





T. Akutsu, Y. Saito, Y. Sakakibara et al., Opt. Mater. Express **6**, 1613 (2016)

Black surface

Common requirements:
- Vacuum compatibility: < 10^{-7} Pa
- As low reflectivity as possible at 1064 nm
- Industrial applicability for large areas up to φ 800 mm

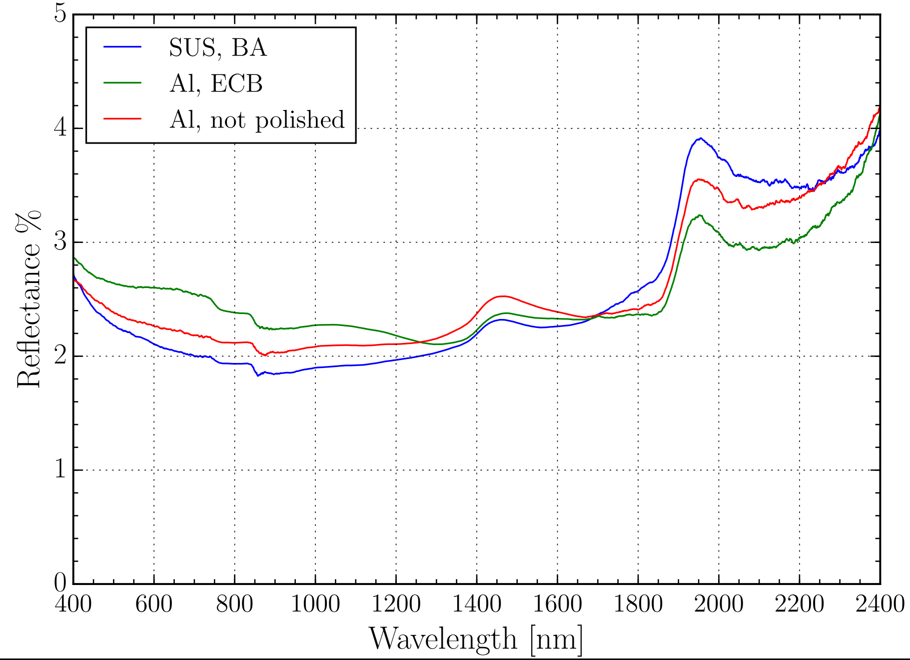
For cryoduct shields (#2):
- Cryogenic compatibility: < 80 K
- As low reflectivity as possible for 300 K radiation (10 um)
- Applicability to aluminum

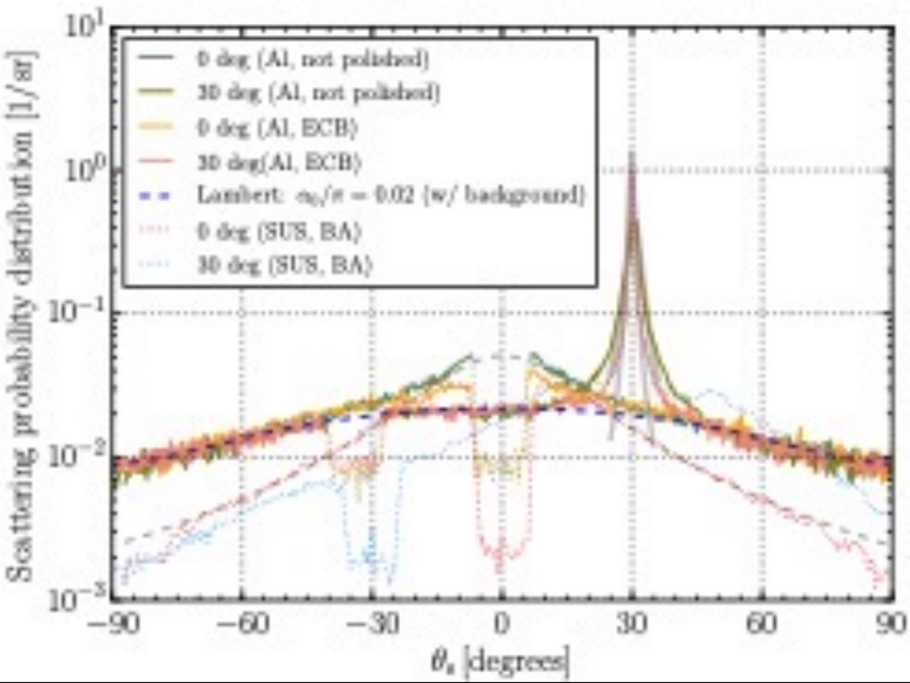
For wide-angle baffles (#4):
- More cryogenic compatibility: < 8 K

Getting stringent!

Unique to KAGRA

→ Considering these requirements, we chose a black Ni-plating family one for mid- to large-size baffles.

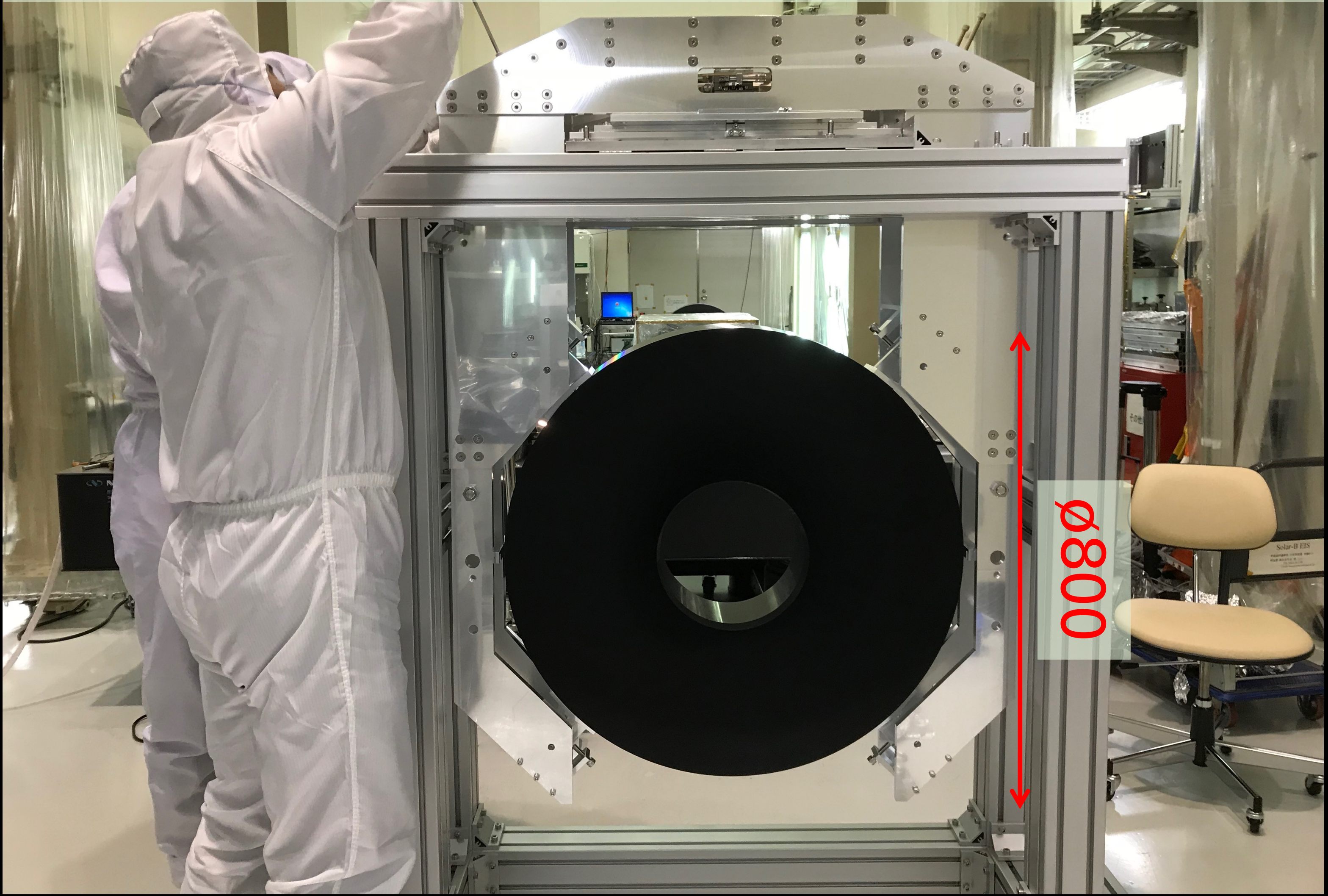




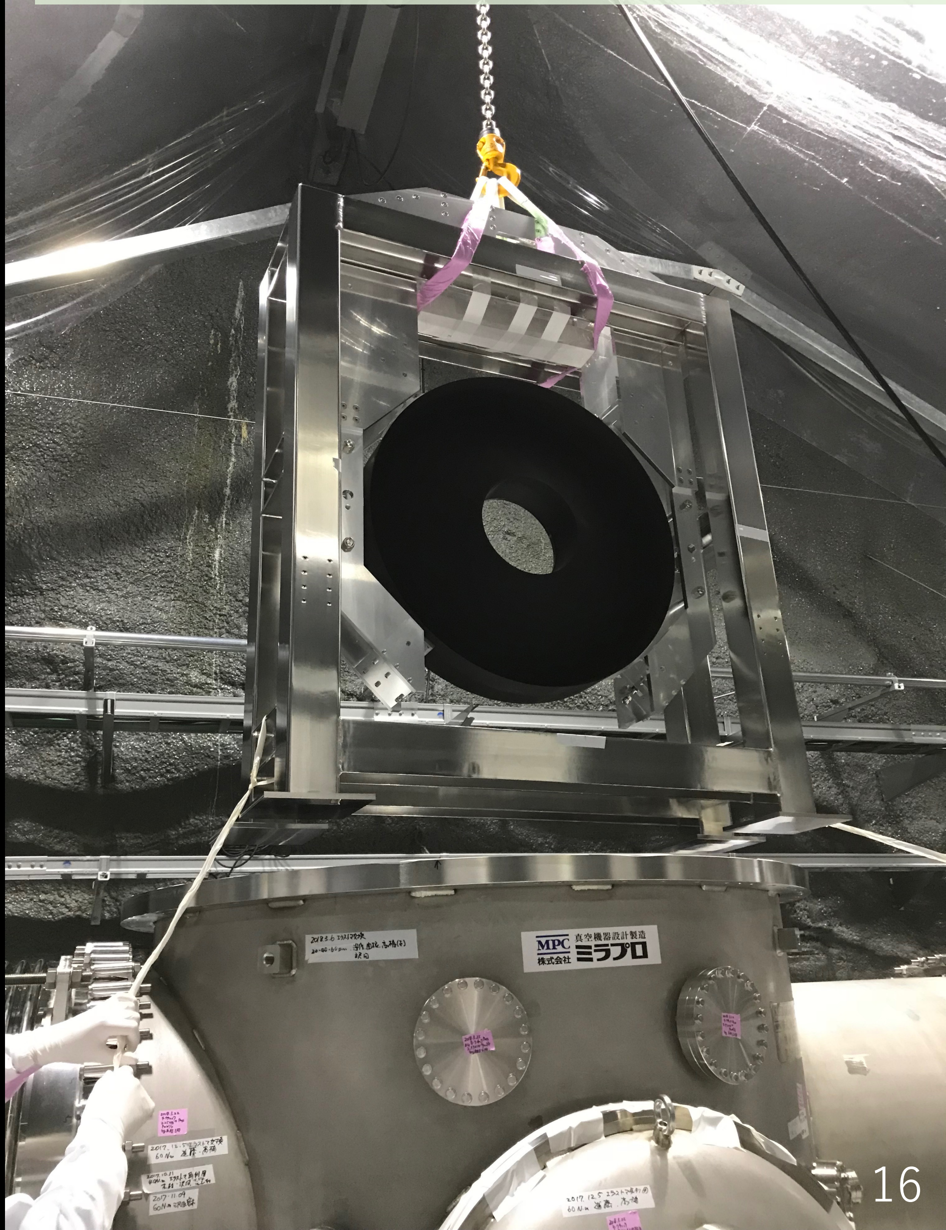
T. Akutsu, Y. Saito, Y. Sakakibara et al., Opt. Mater. Express **6**, 1613 (2016)

Narrow-angle baffles (NAB)

At the Advanced Technology Center (ATC) in NAOJ.
Assy of the NAB and its suspension.

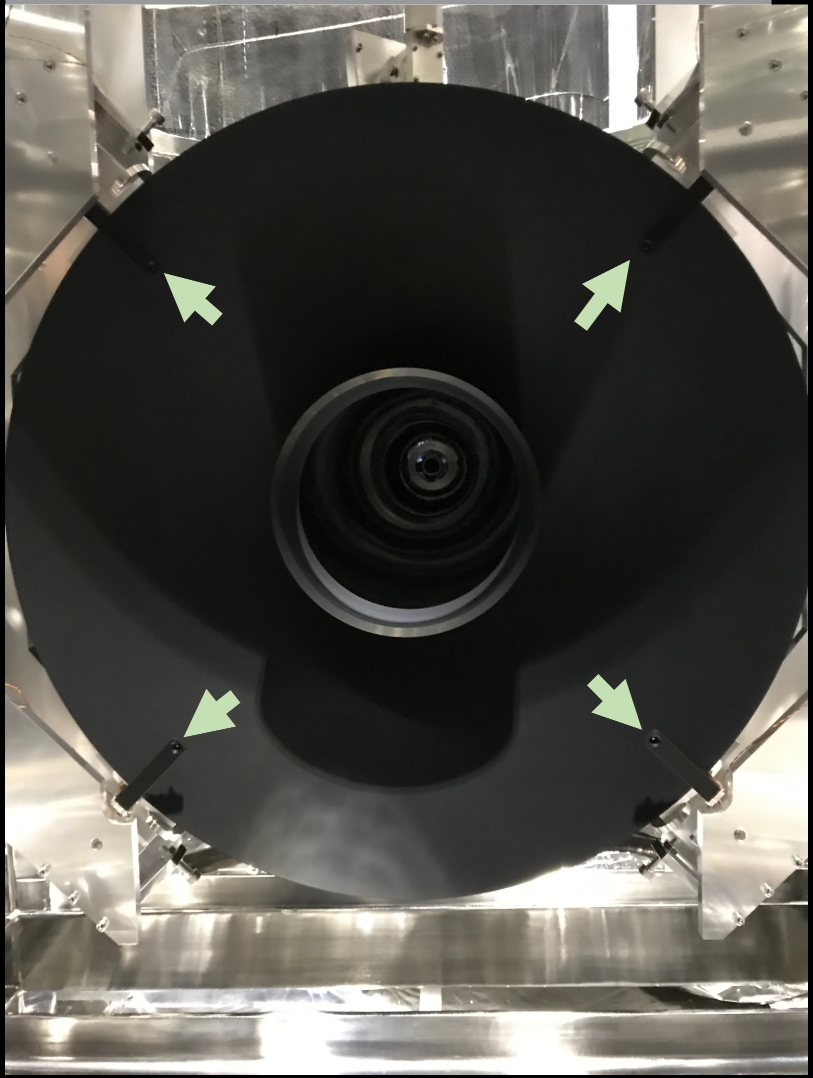


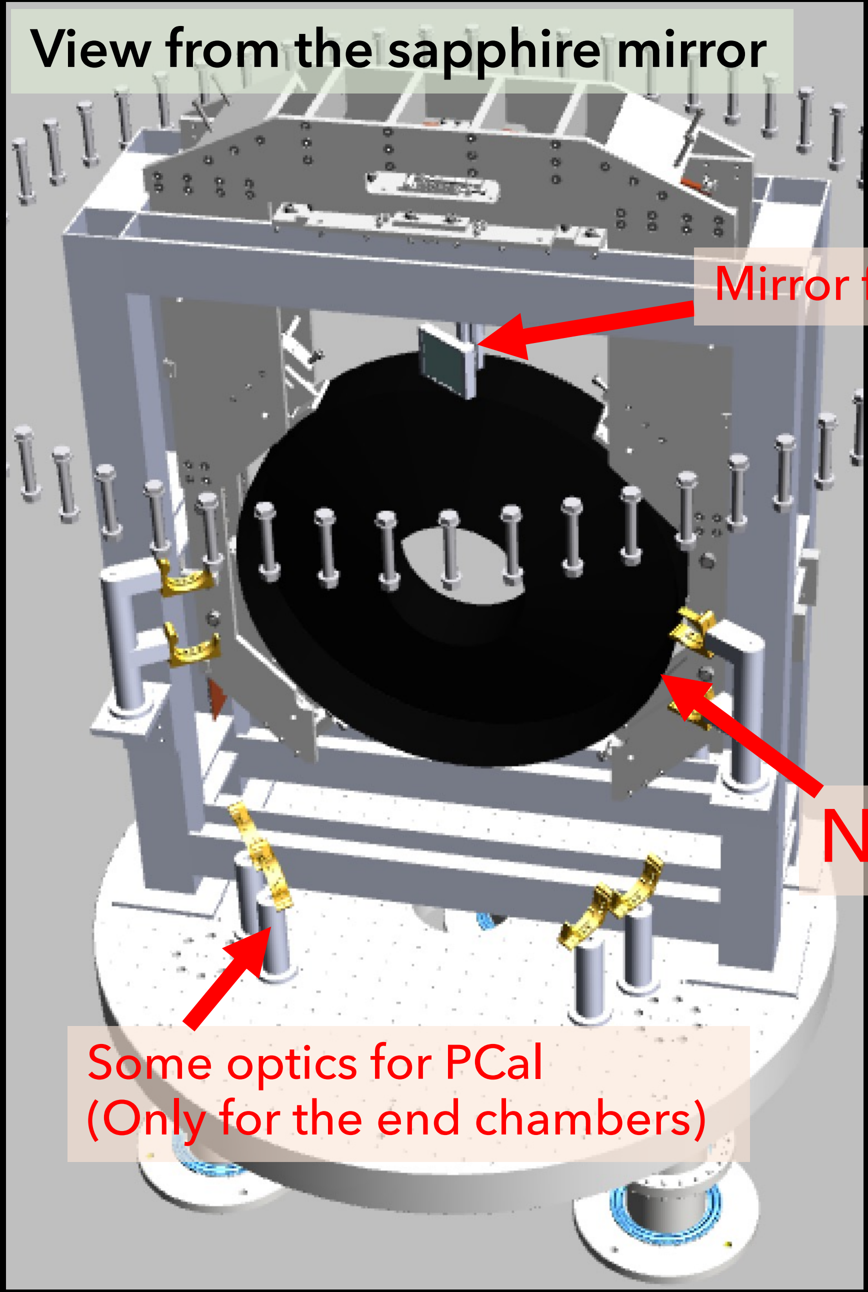
Installing the NAB into a chamber.

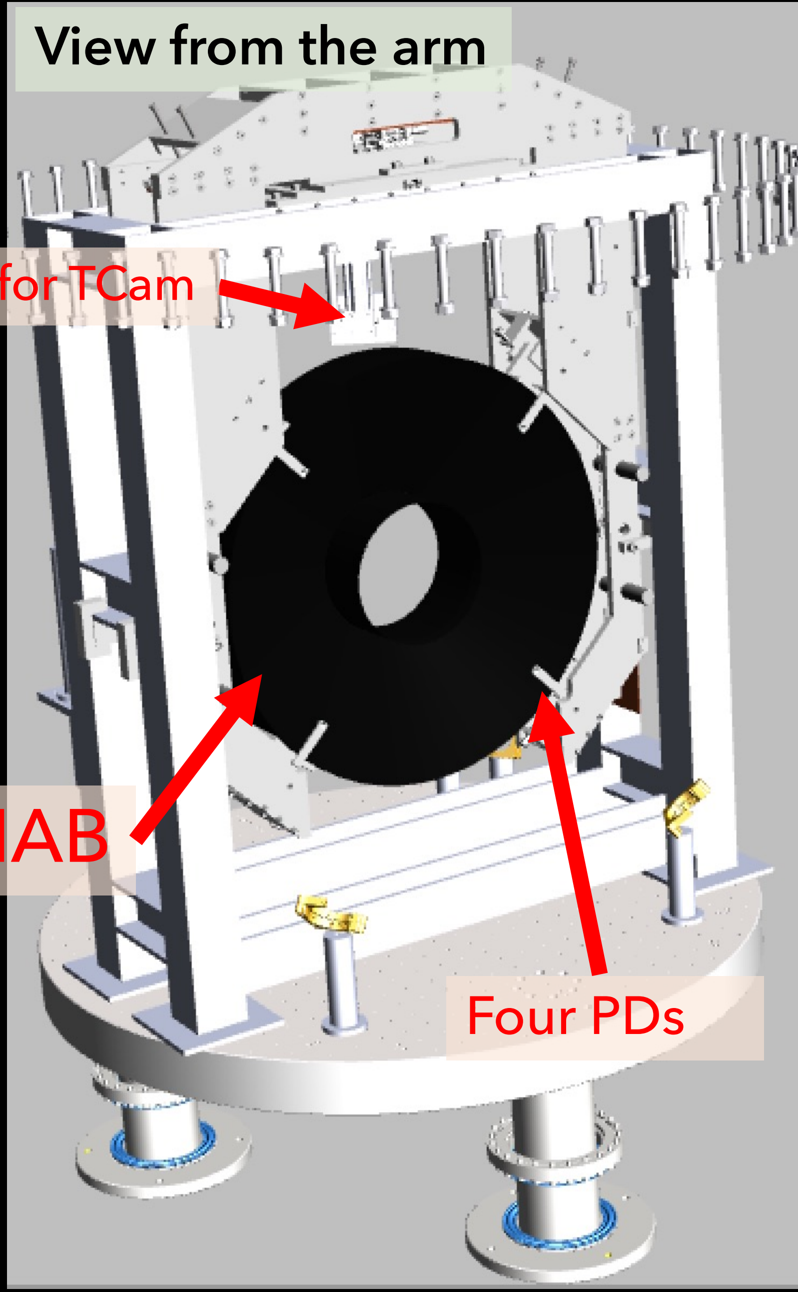


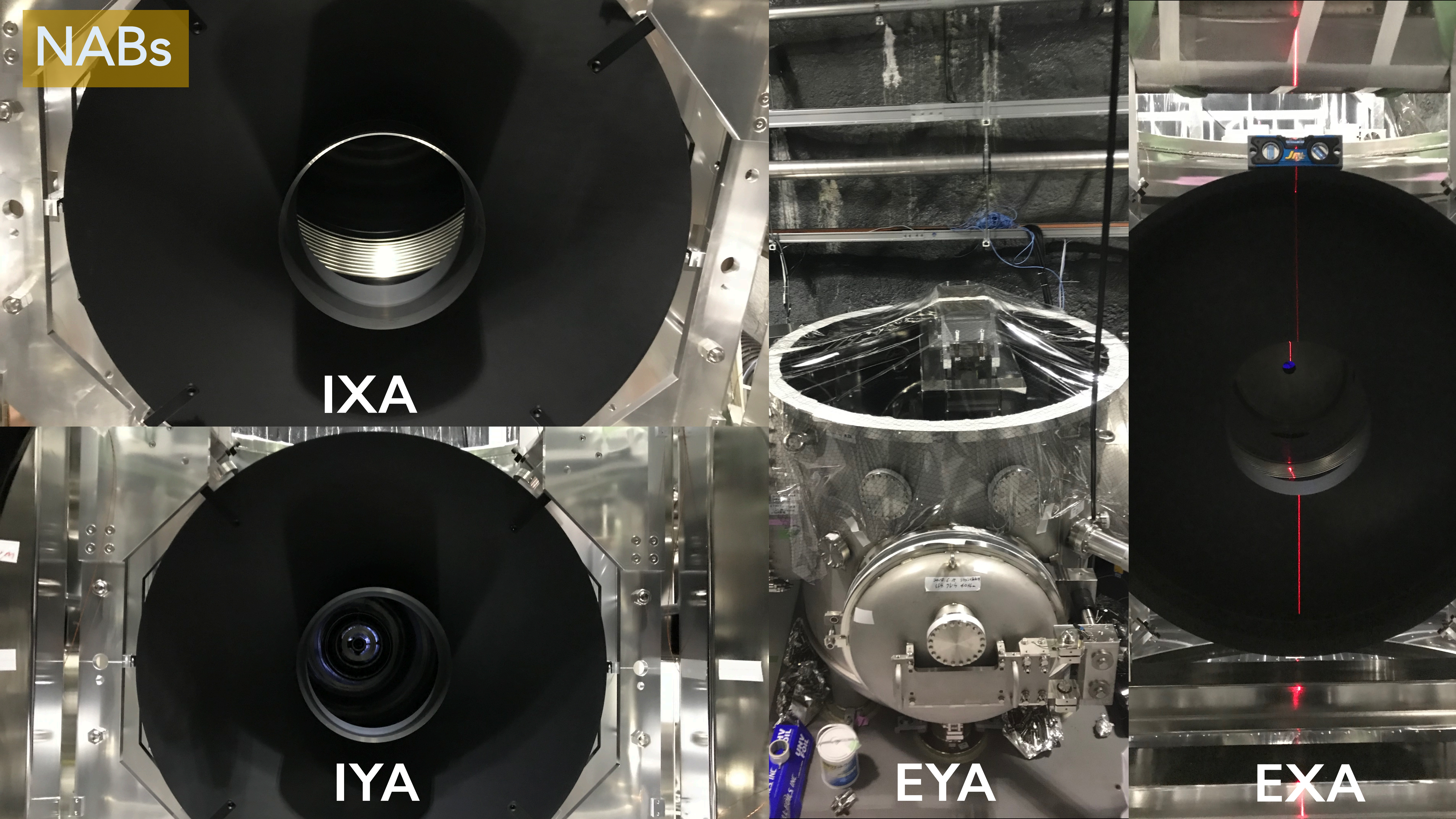
With four PDs

https://klog.icrr.u-tokyo.ac.jp/osl/?r=7197



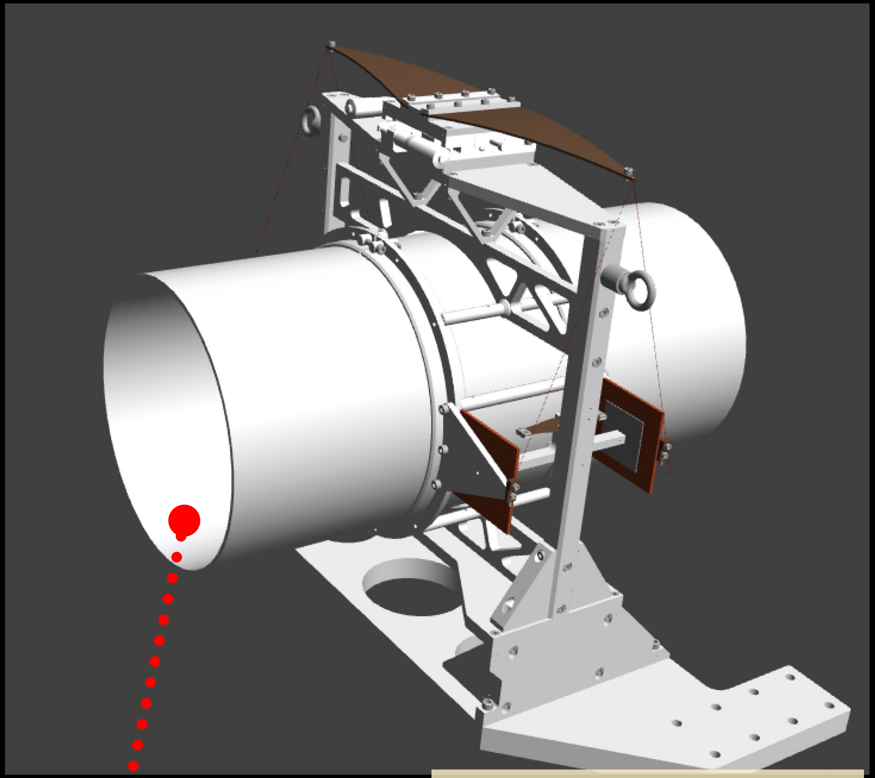





NABs
IXA
IYA
EYA
EXA

Wide-angle baffles (WABs)

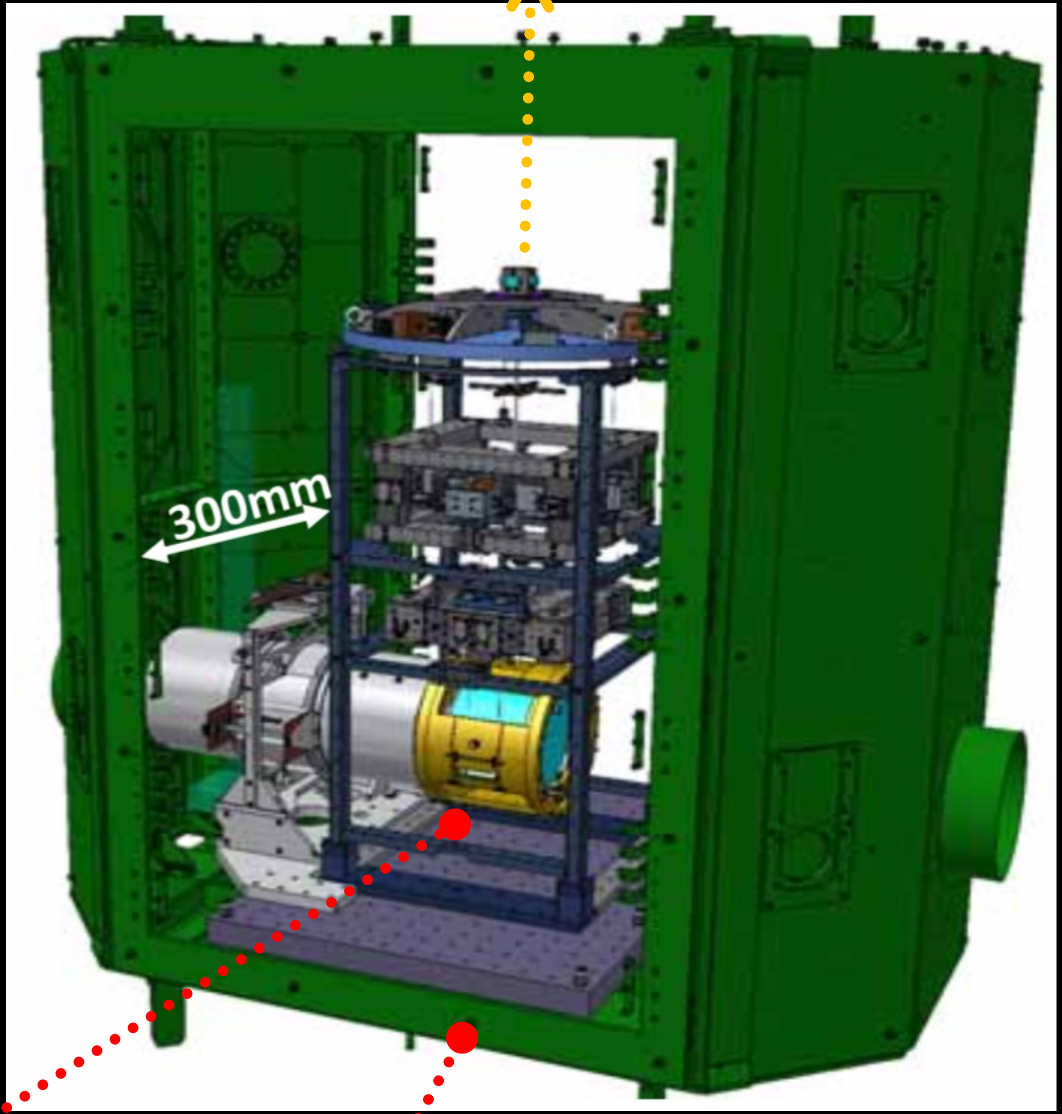
- To be cooled down ~ 15K without IR beams
- Over 4W input from the mirror → heat up to ~20K or so



Design: ATC/NAOJ

Inside: black coated

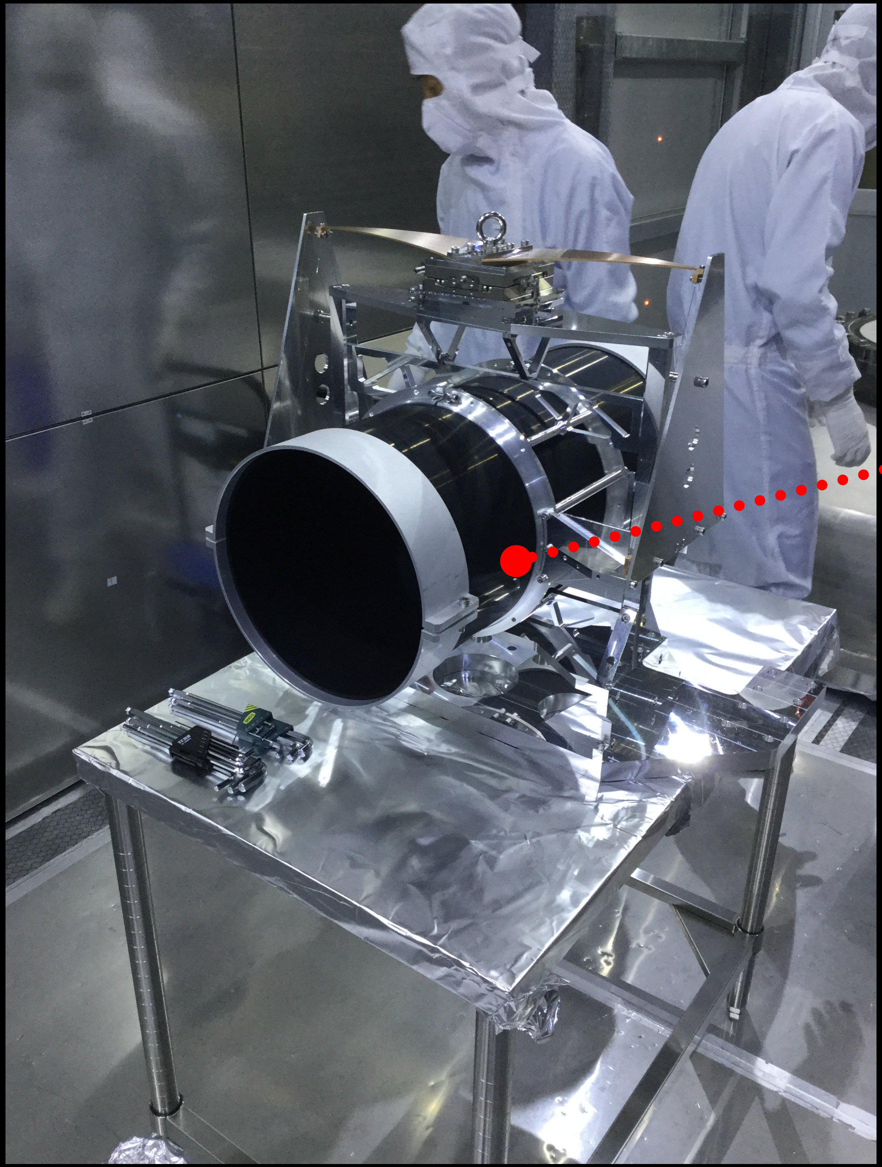
From14 m above

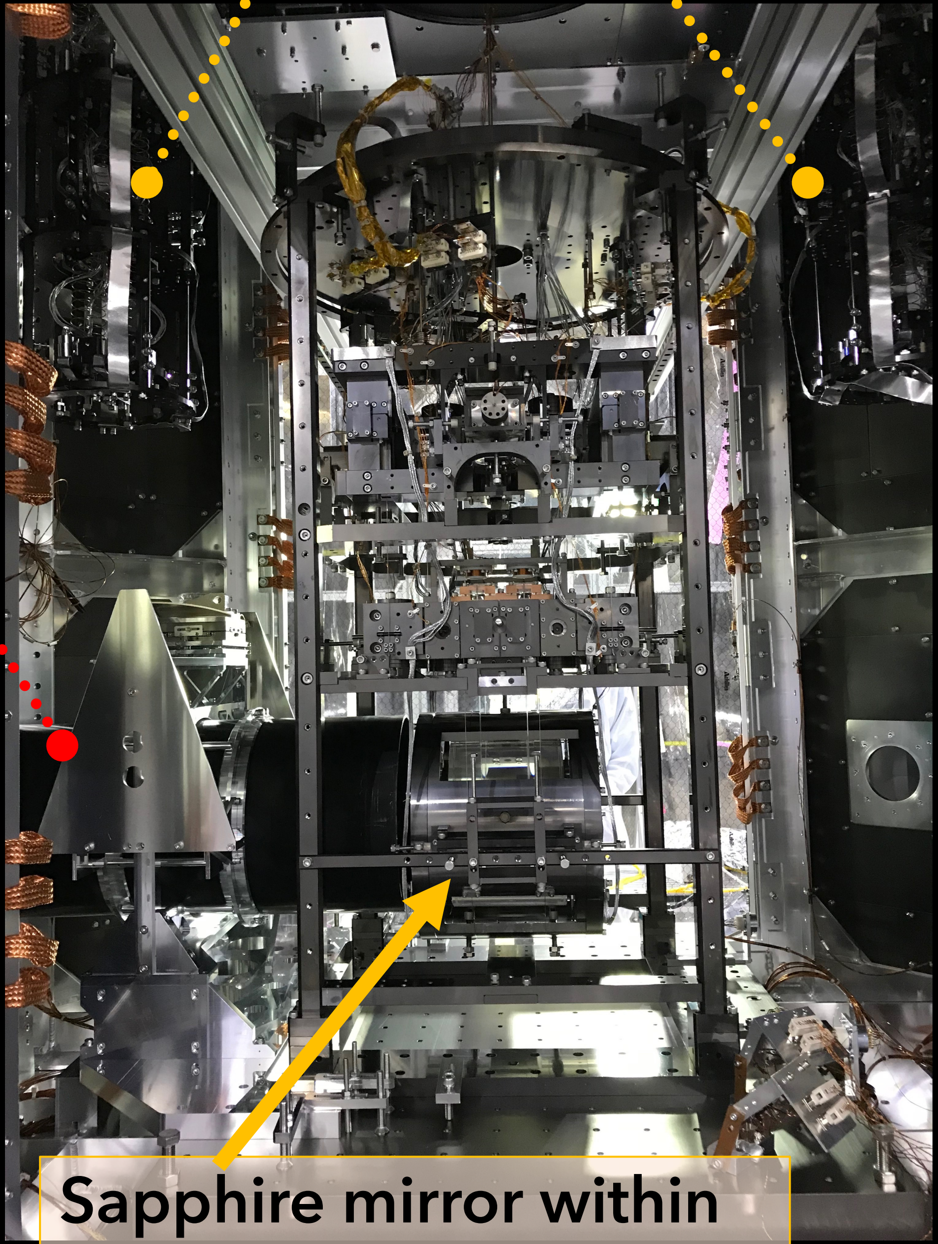


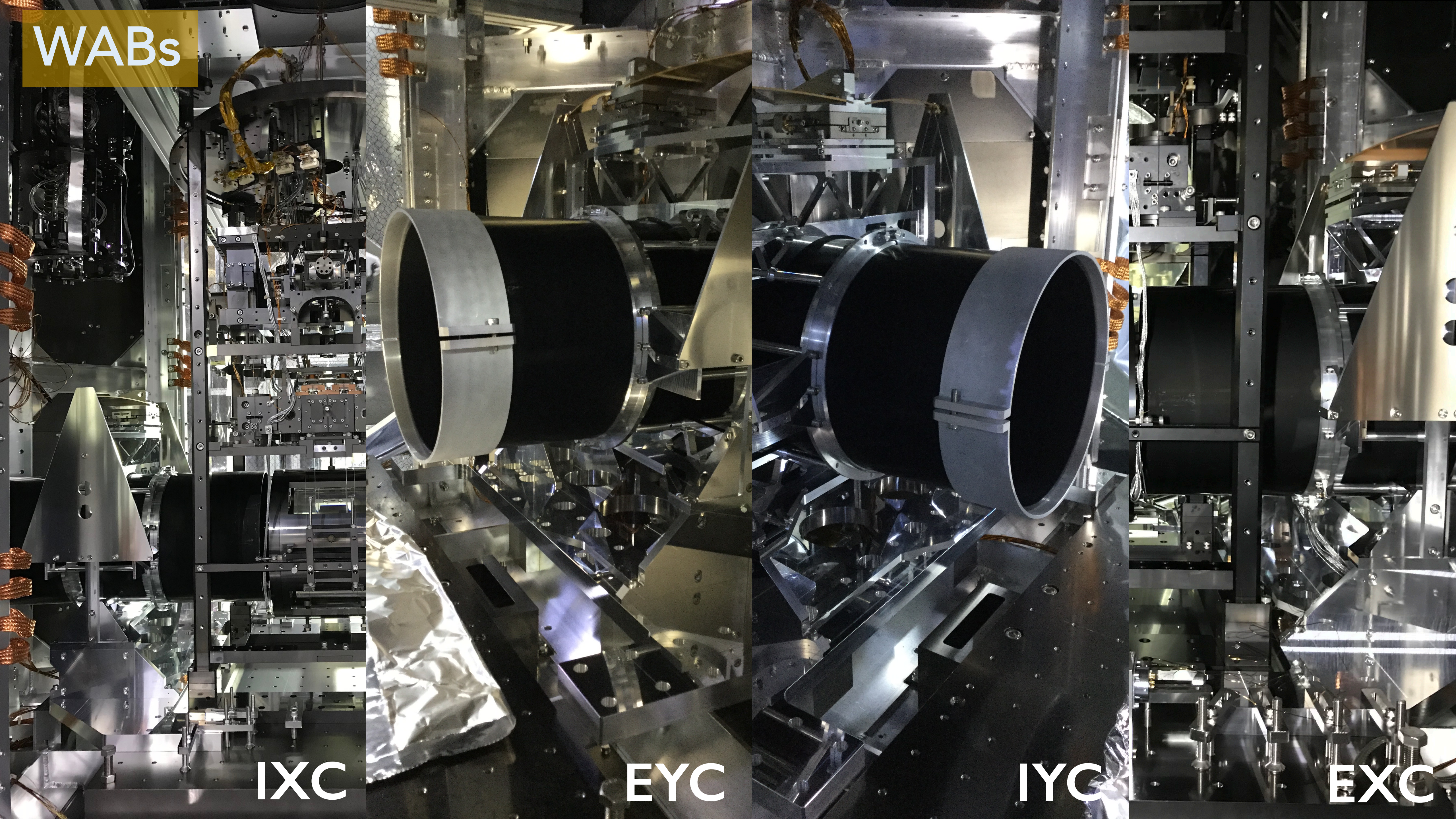
Sapphire mirror

Cryostat 8K shield

Installed in the cryostat





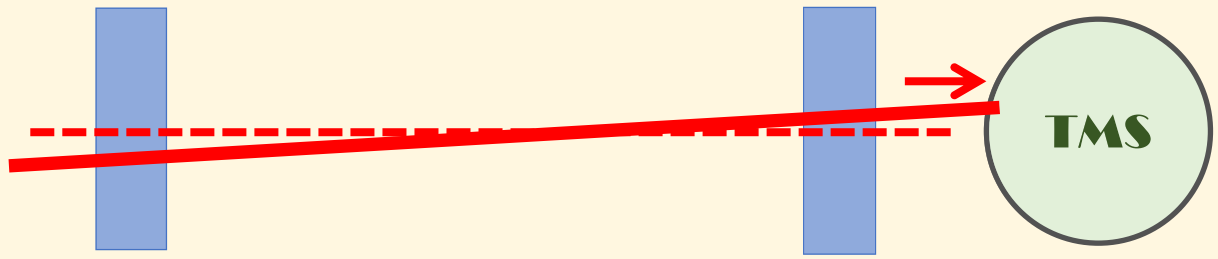

WABs
IXC
EYC
IYC
EXC

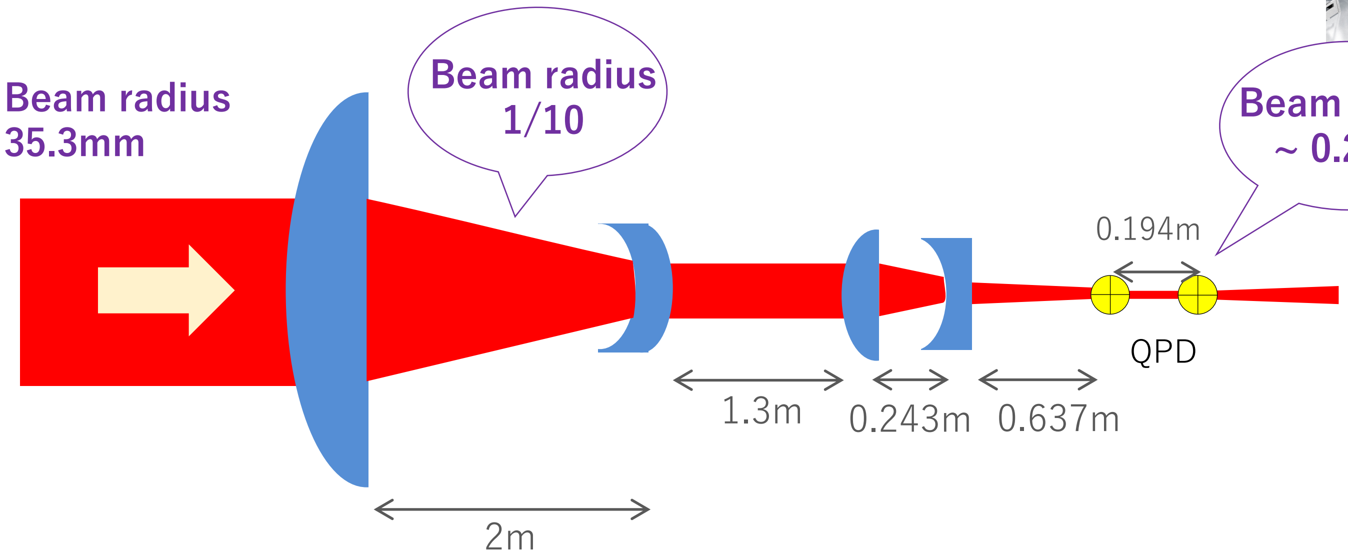
透過光モニター

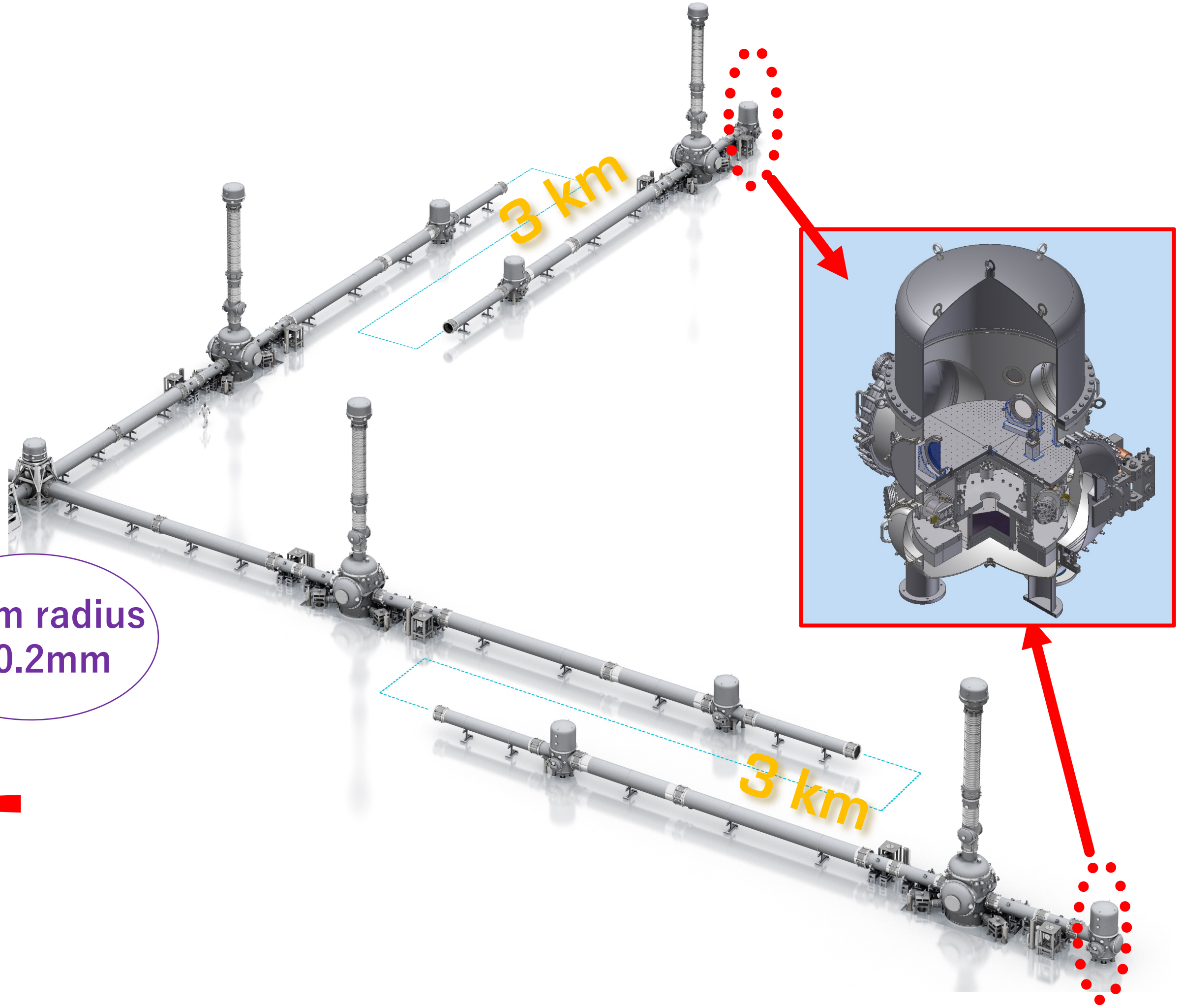
Transmission monitors (TMS)

Transmission monitor

- To detector tilt and shif of the 3 km optical axes
- (And monitoring the transmitted beam's shape & power.)

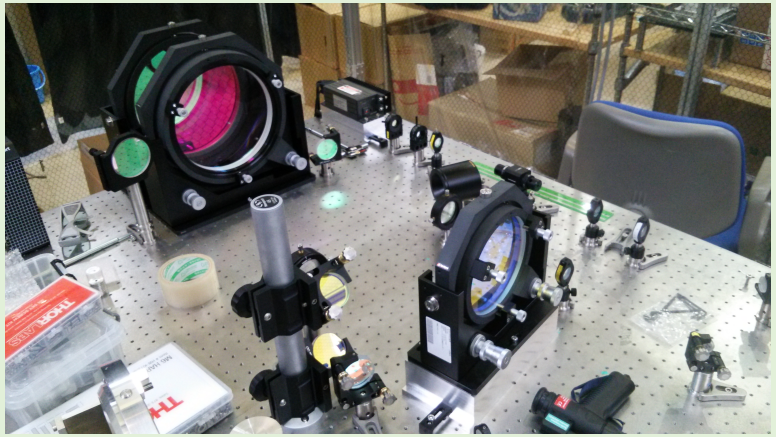


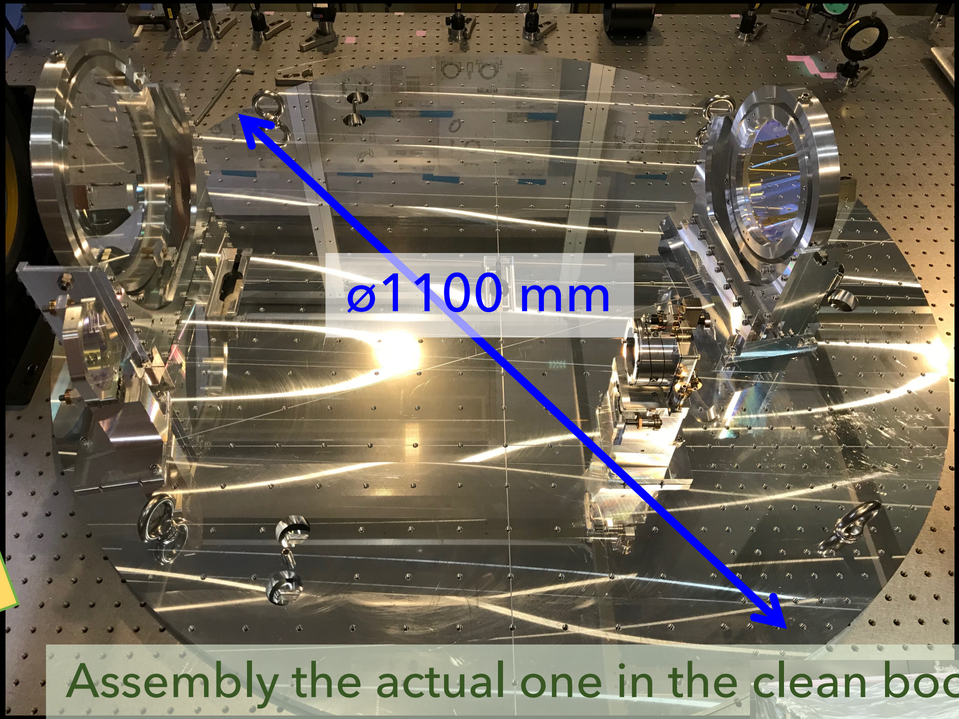


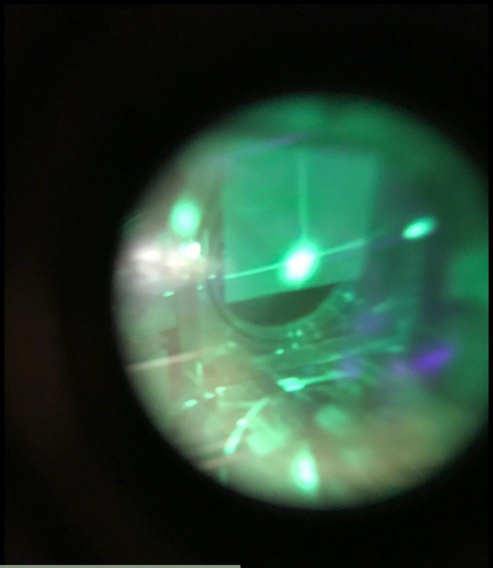


Prototype test and Assembly

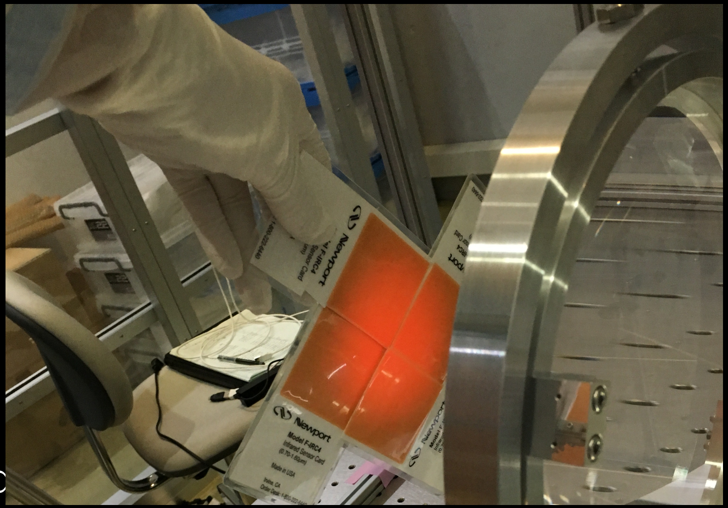
Prototyping.

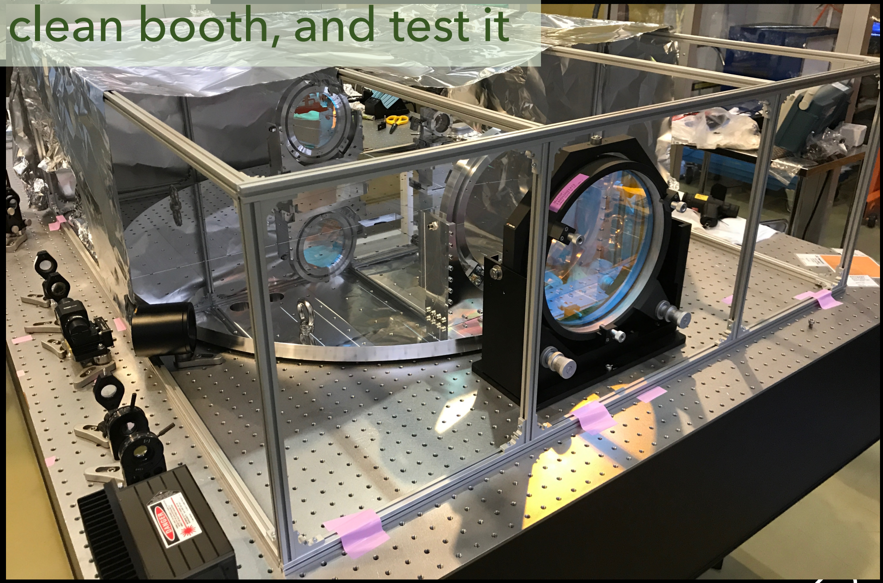






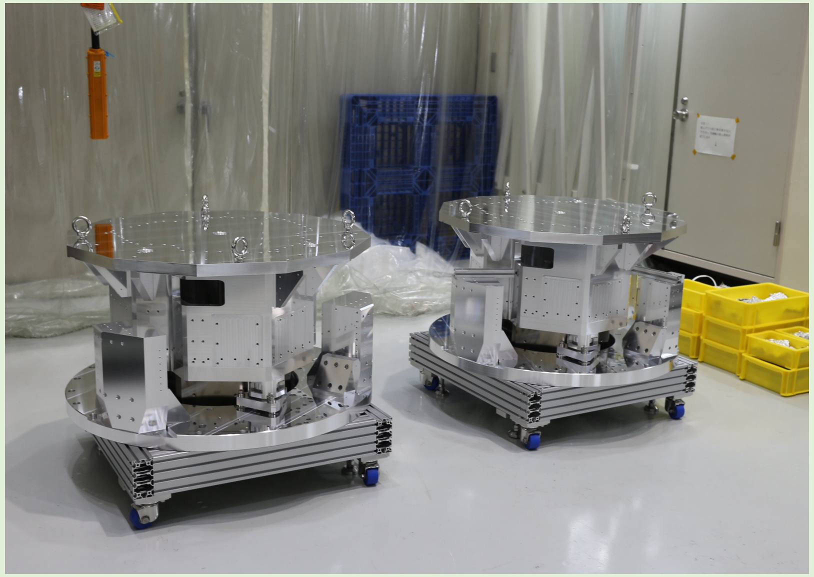
Assembly the actual one in the clean booth, and test it

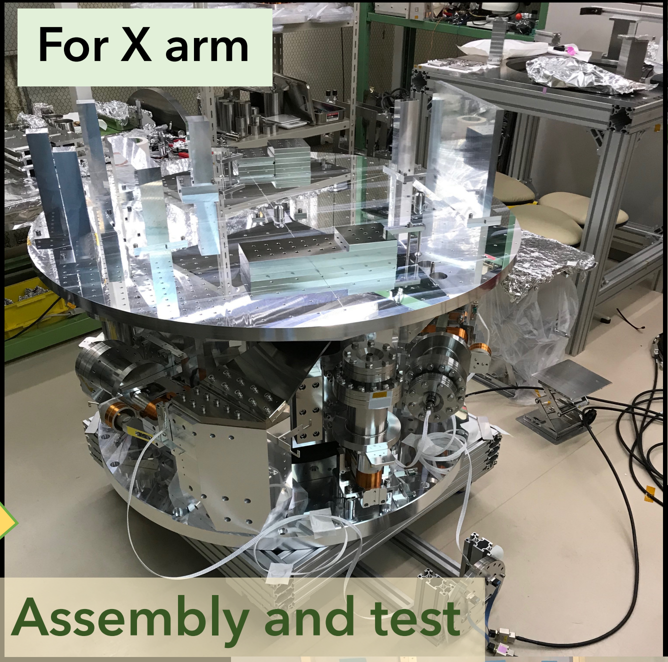




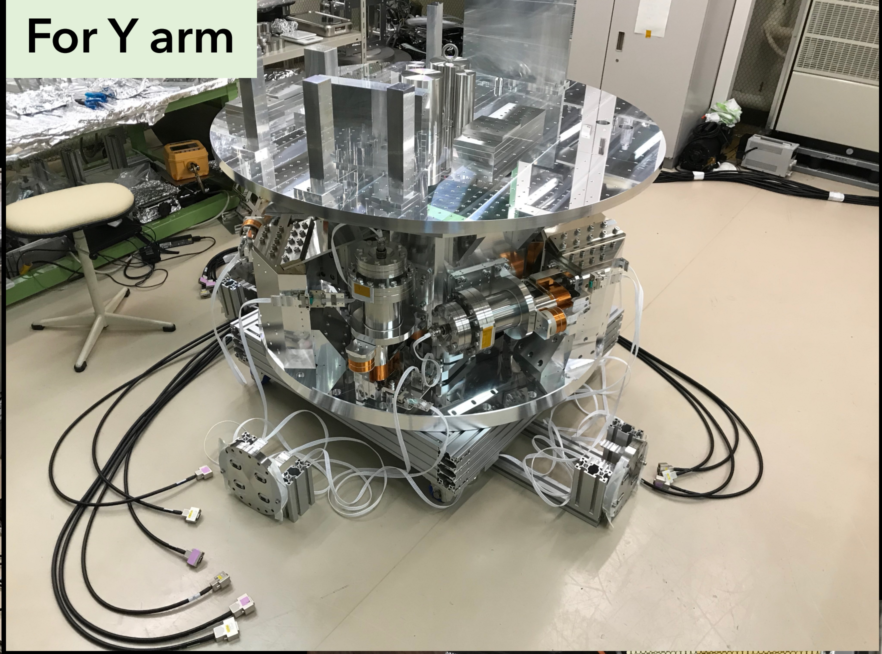
To mitigate stray-ligh noise → vibration isolation stage

Assembly in a large clean room having a crane.



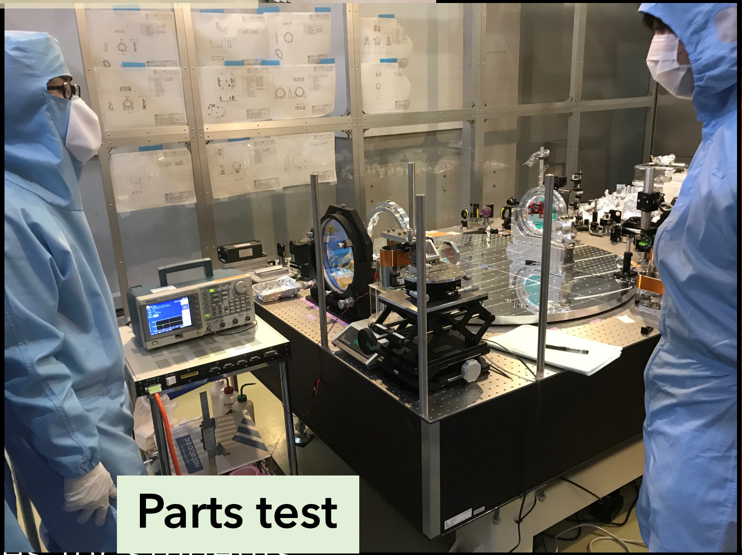


For X arm



For Y arm

Assembly and test



Parts test

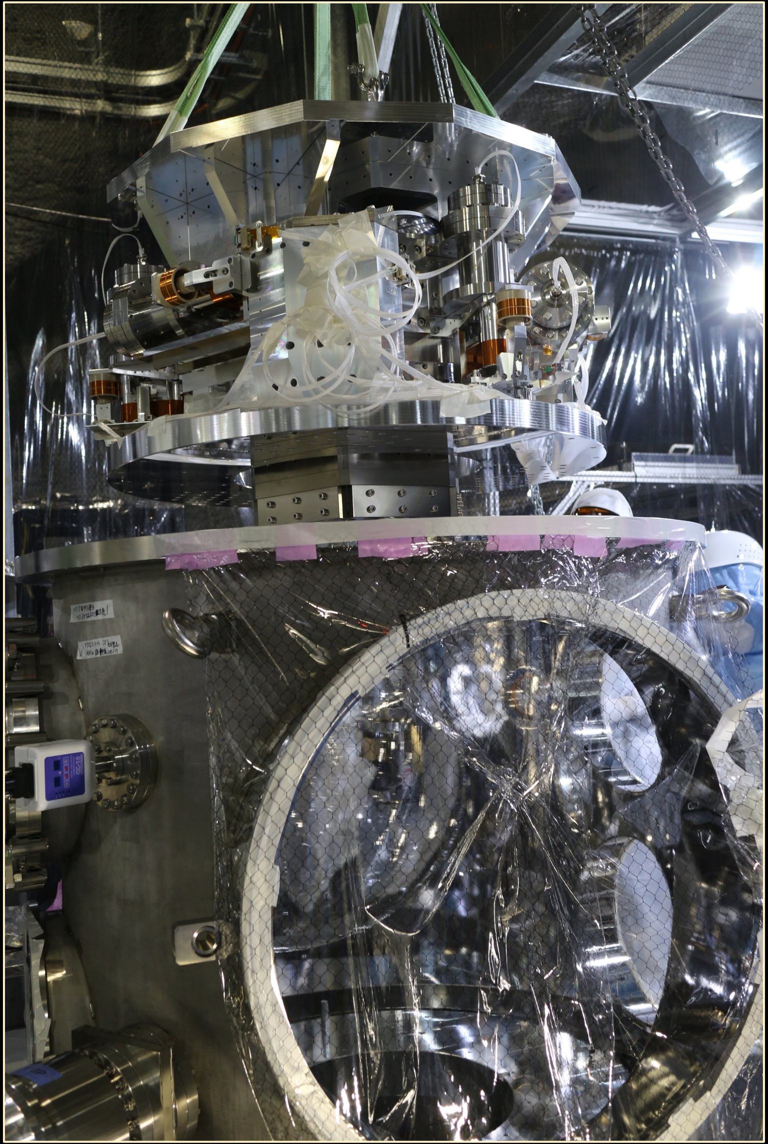
Digital system for controlling these.

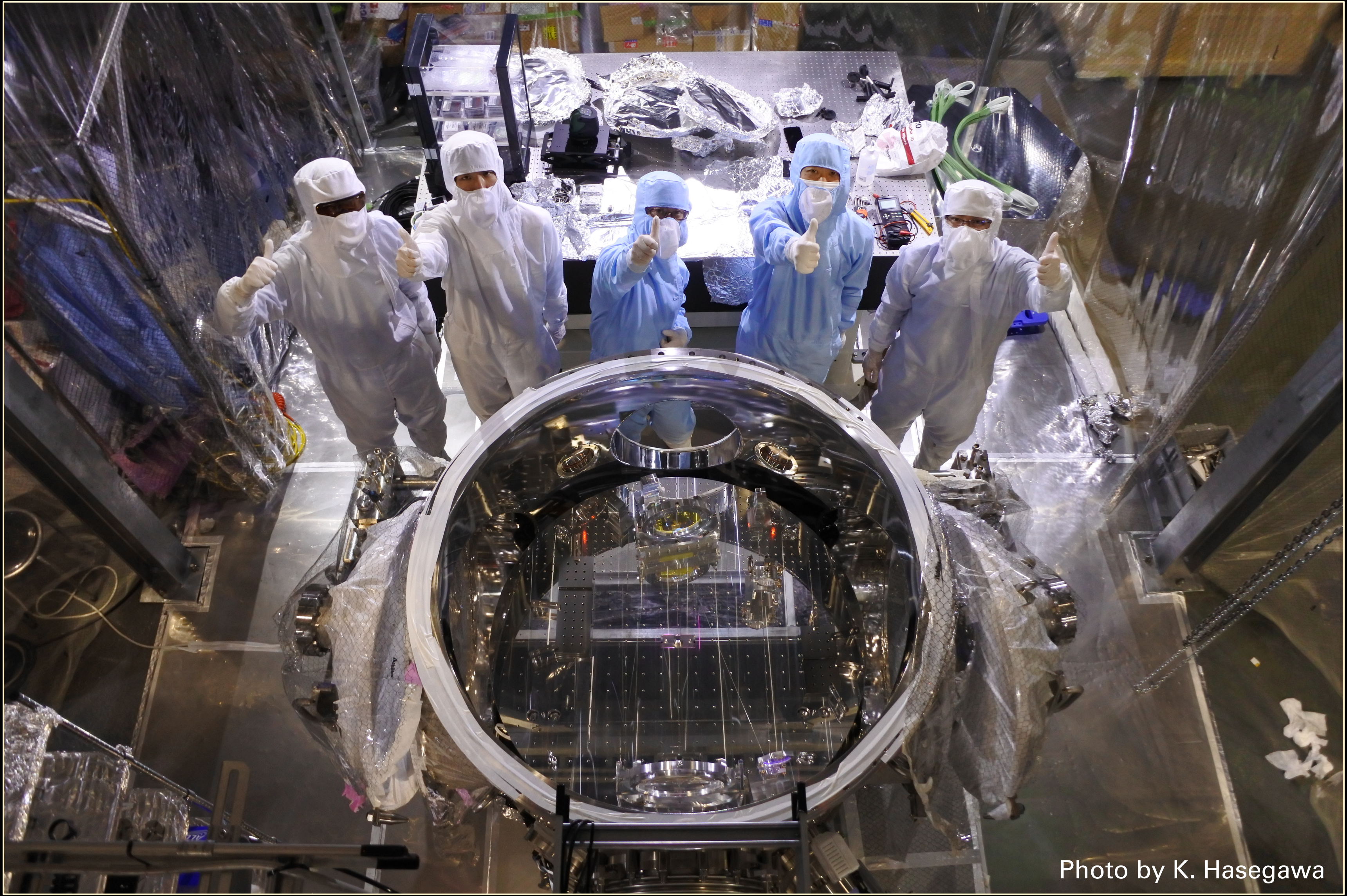
- At the offsite, assembly and test before shipping.
- Then, ship to Kamioka.

To Kamioka

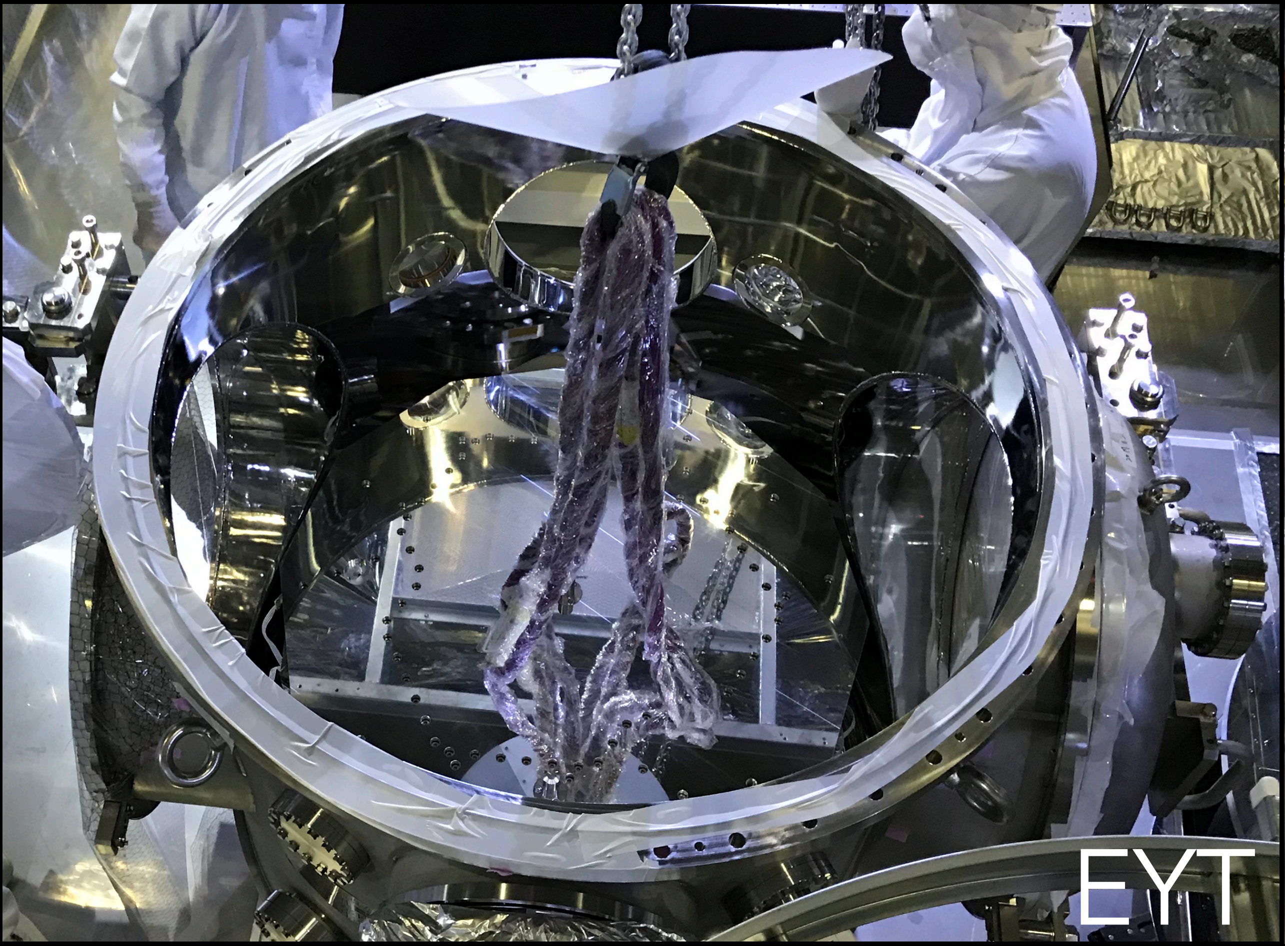
September 2018

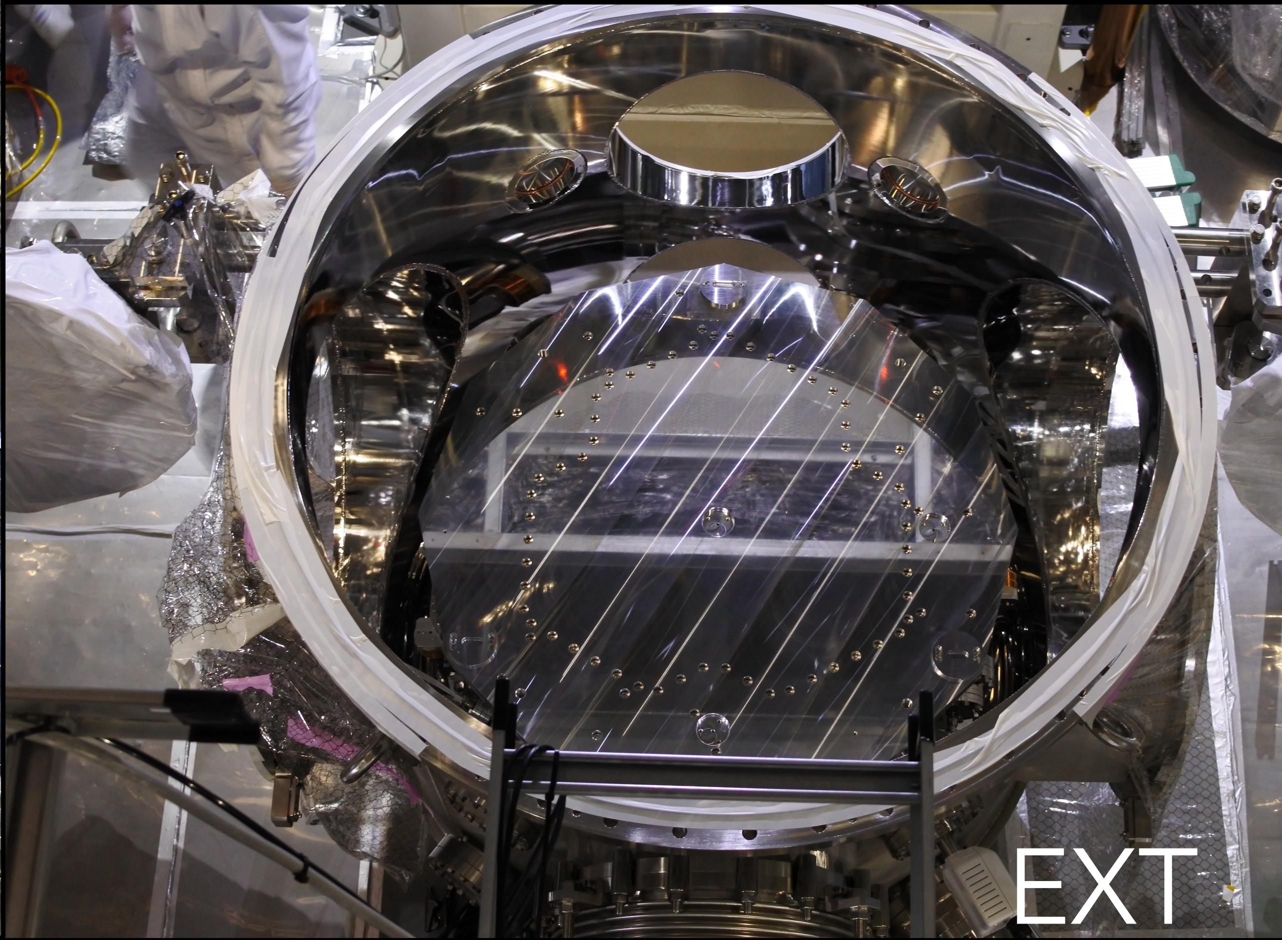
Installing





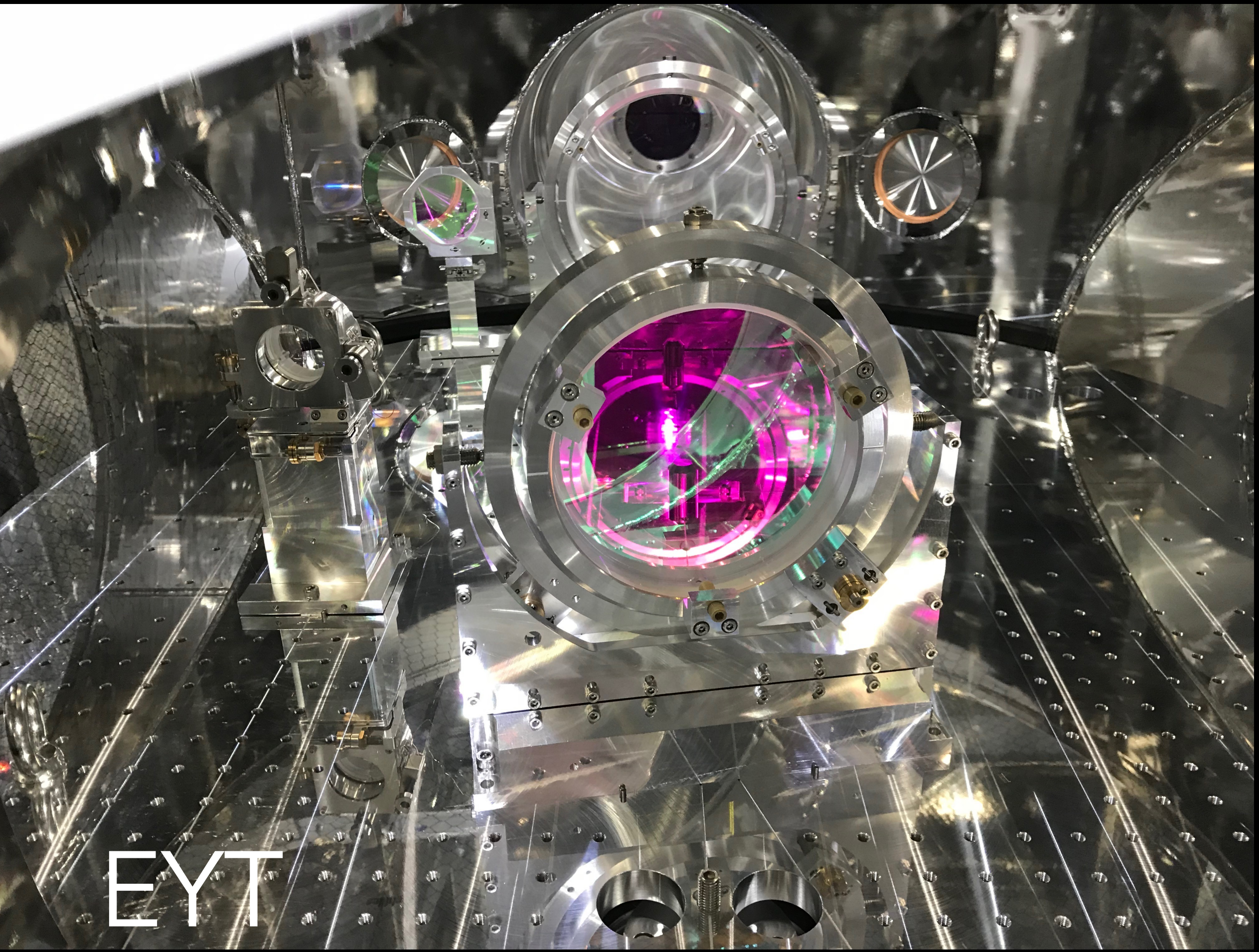
Installed: the vibration isolators

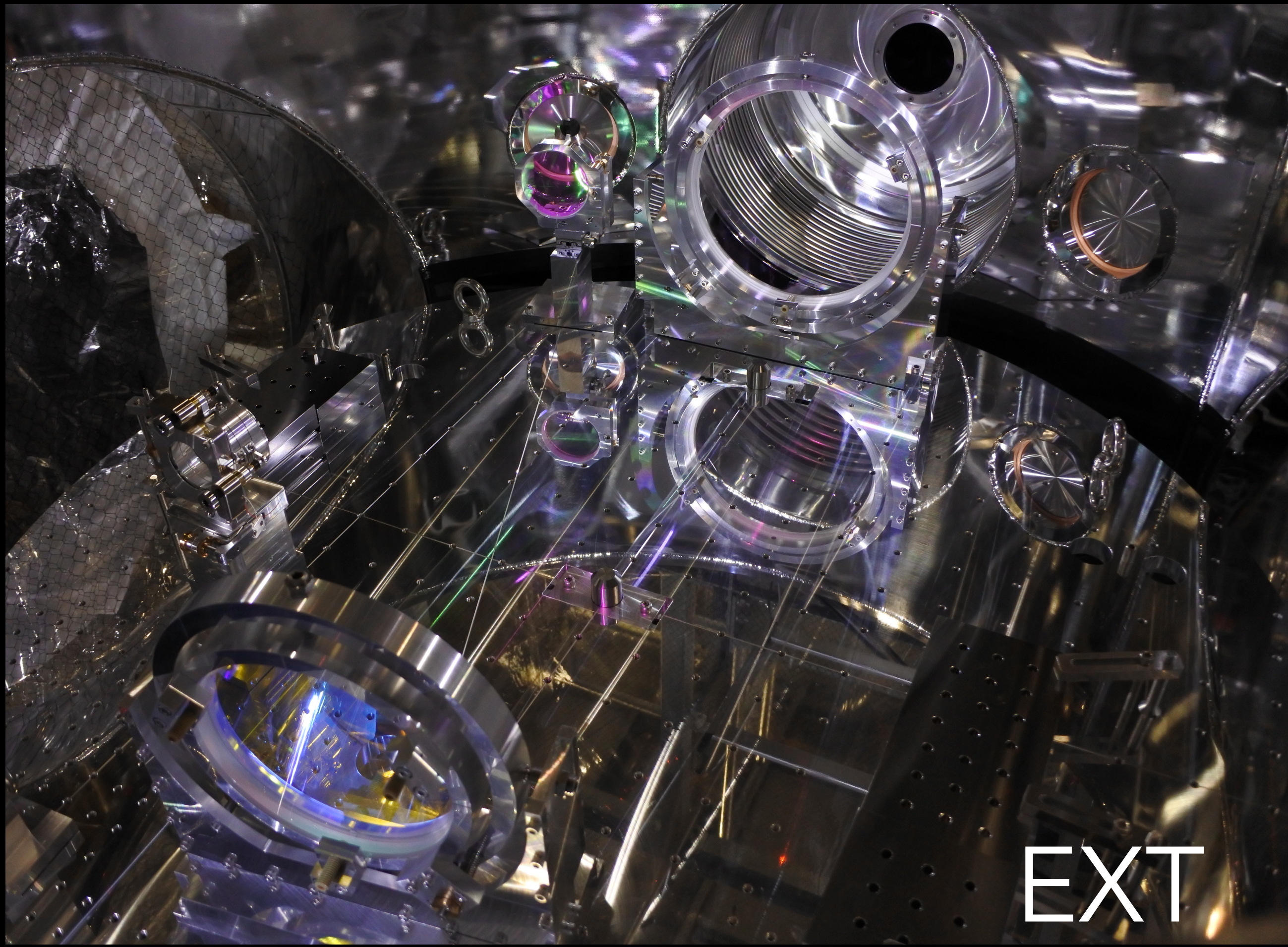




Finally, installed at EYT in this June

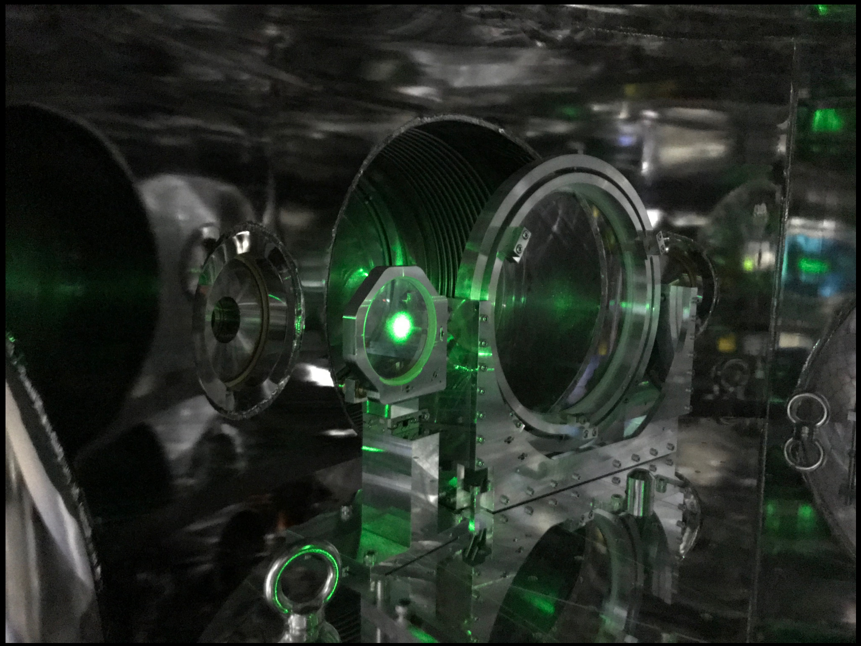
Installed: the optics

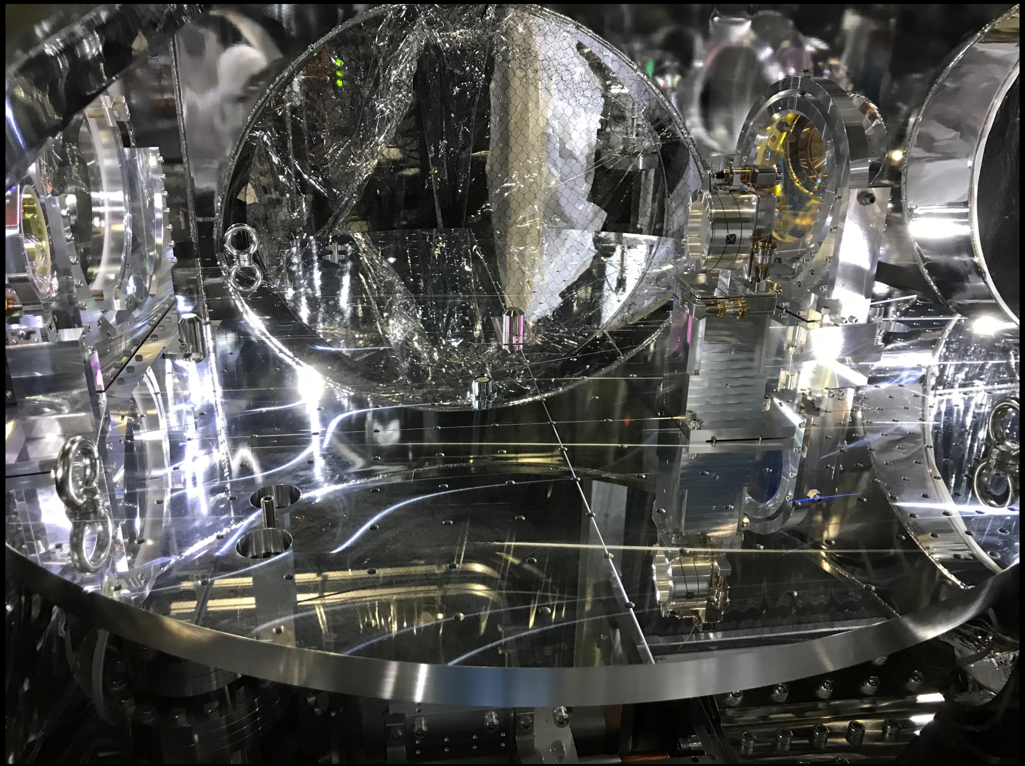


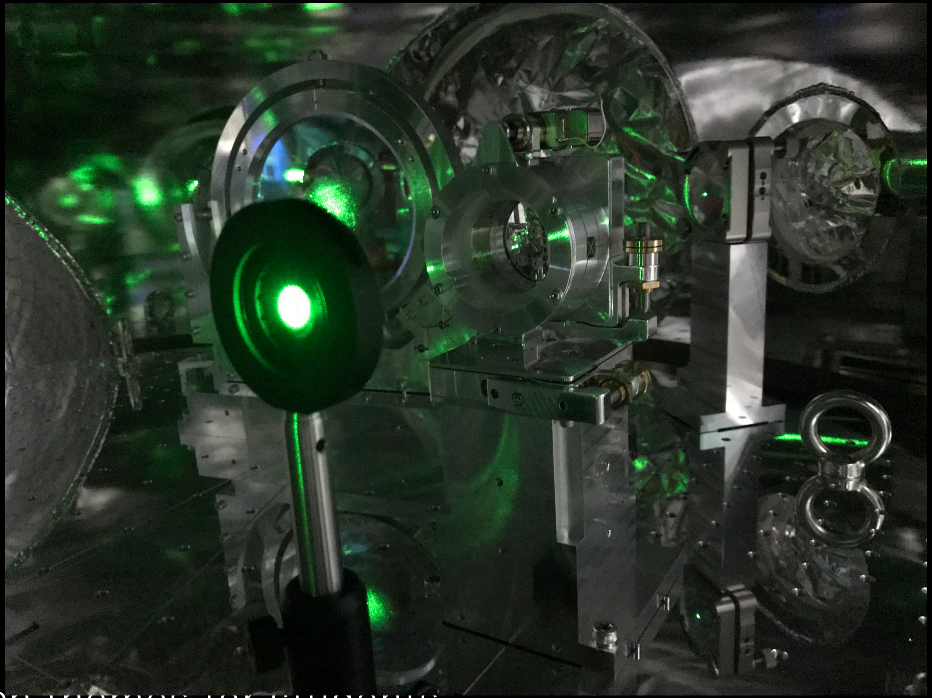


Green (and IR) light

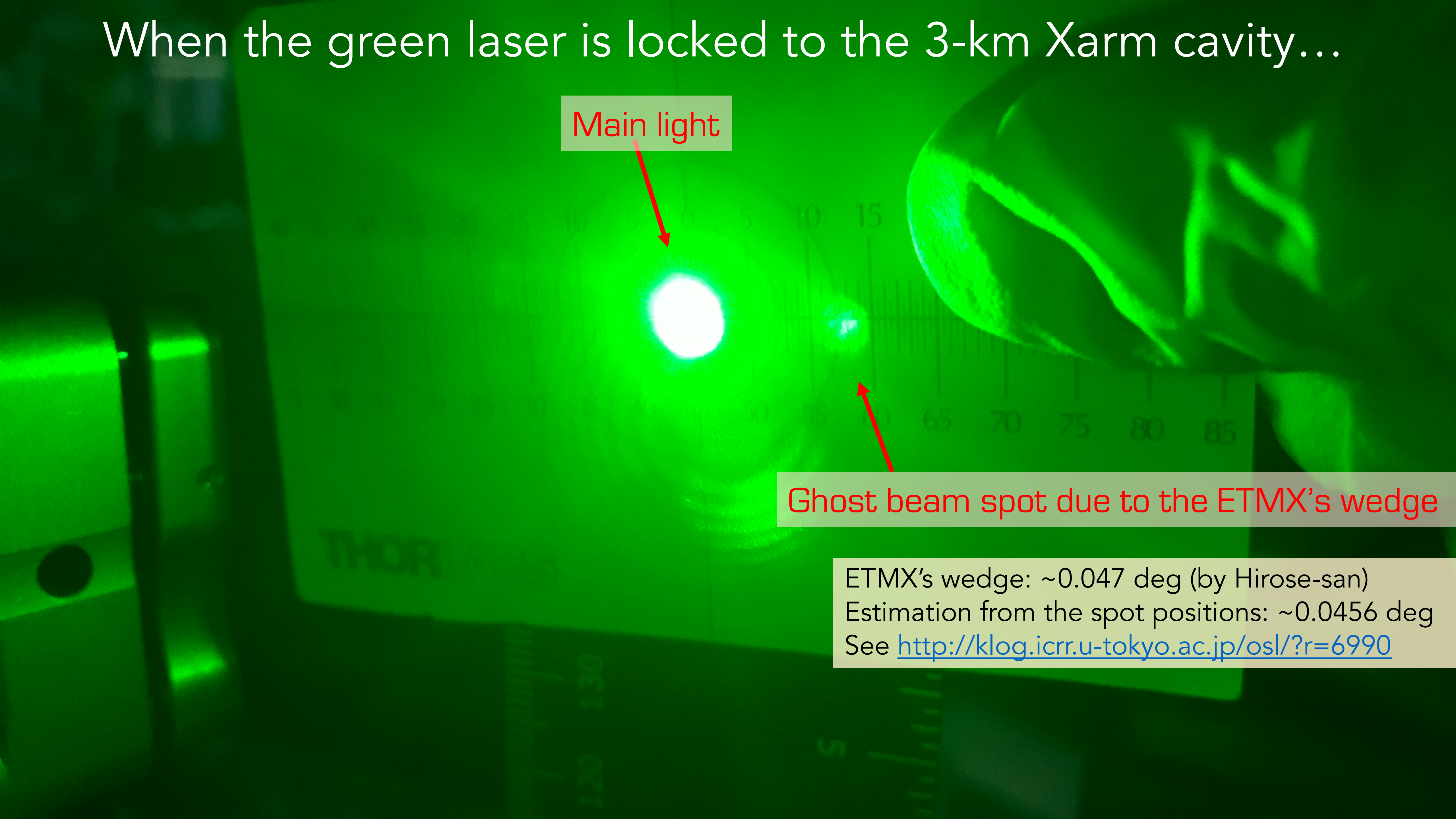
Illuminated by a green (532 nm) light through the 3-km arm→







When the green laser is locked to the 3-km Xarm cavity…



Contents

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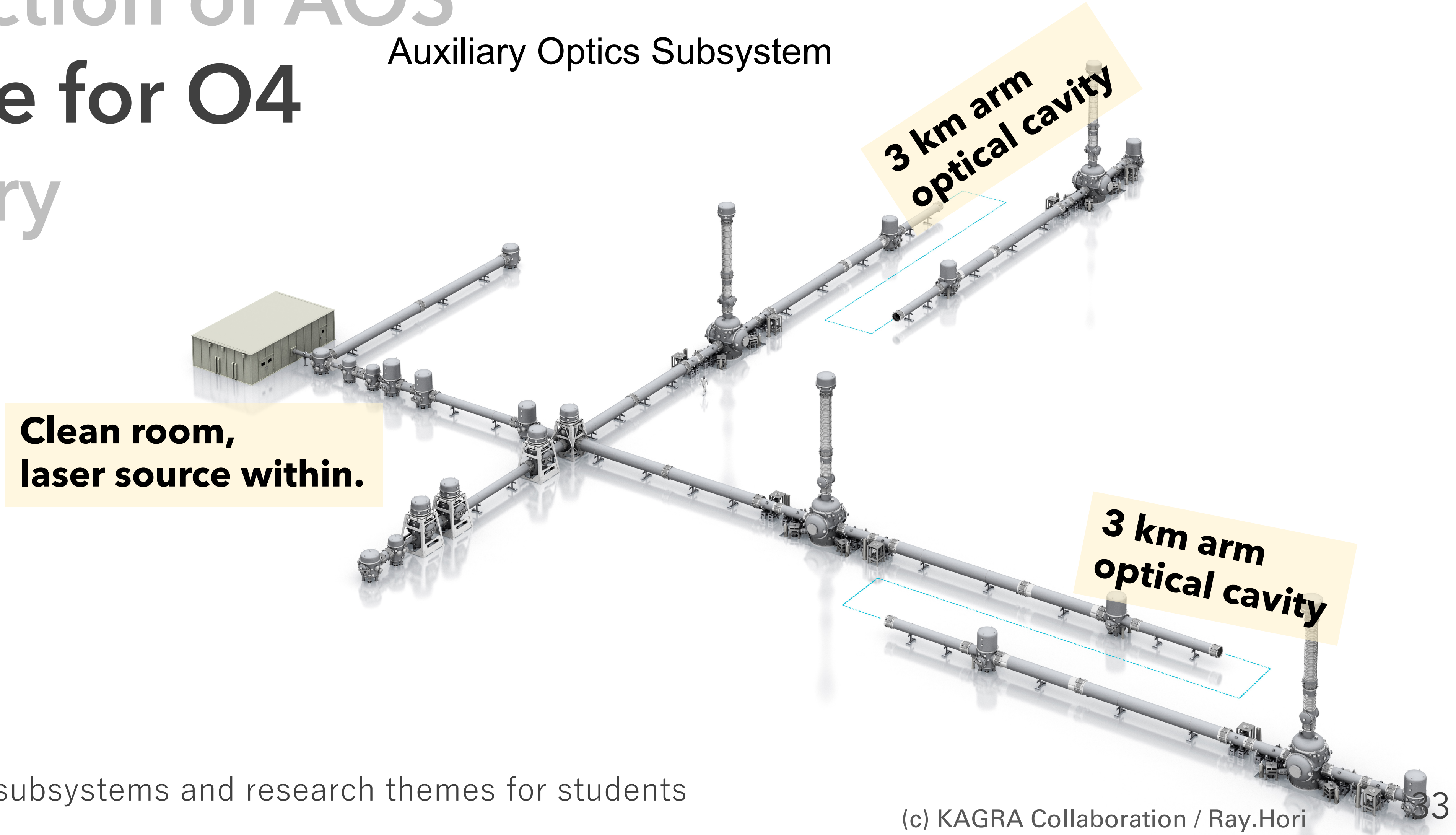
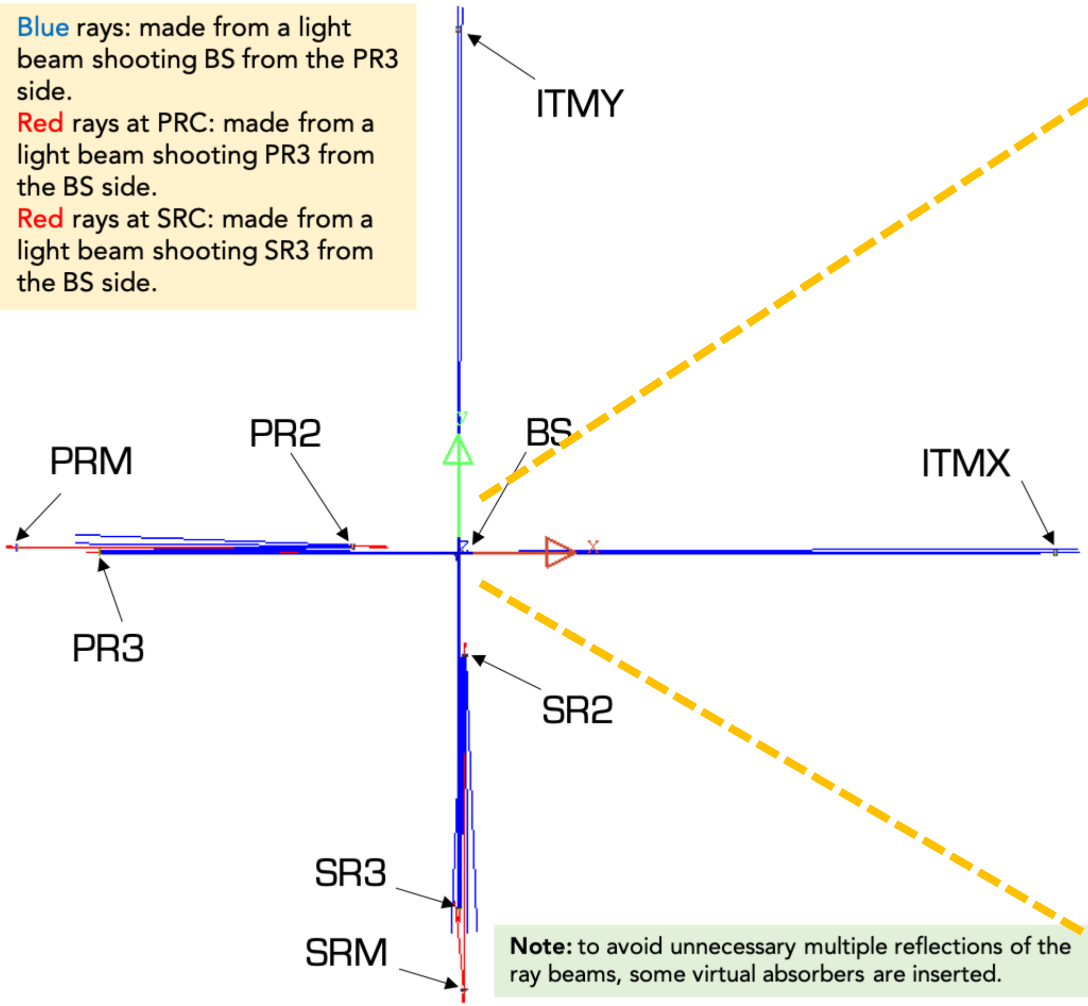
- **Upgrade for O4**
- Summary

Auxiliary Optics Subsystem

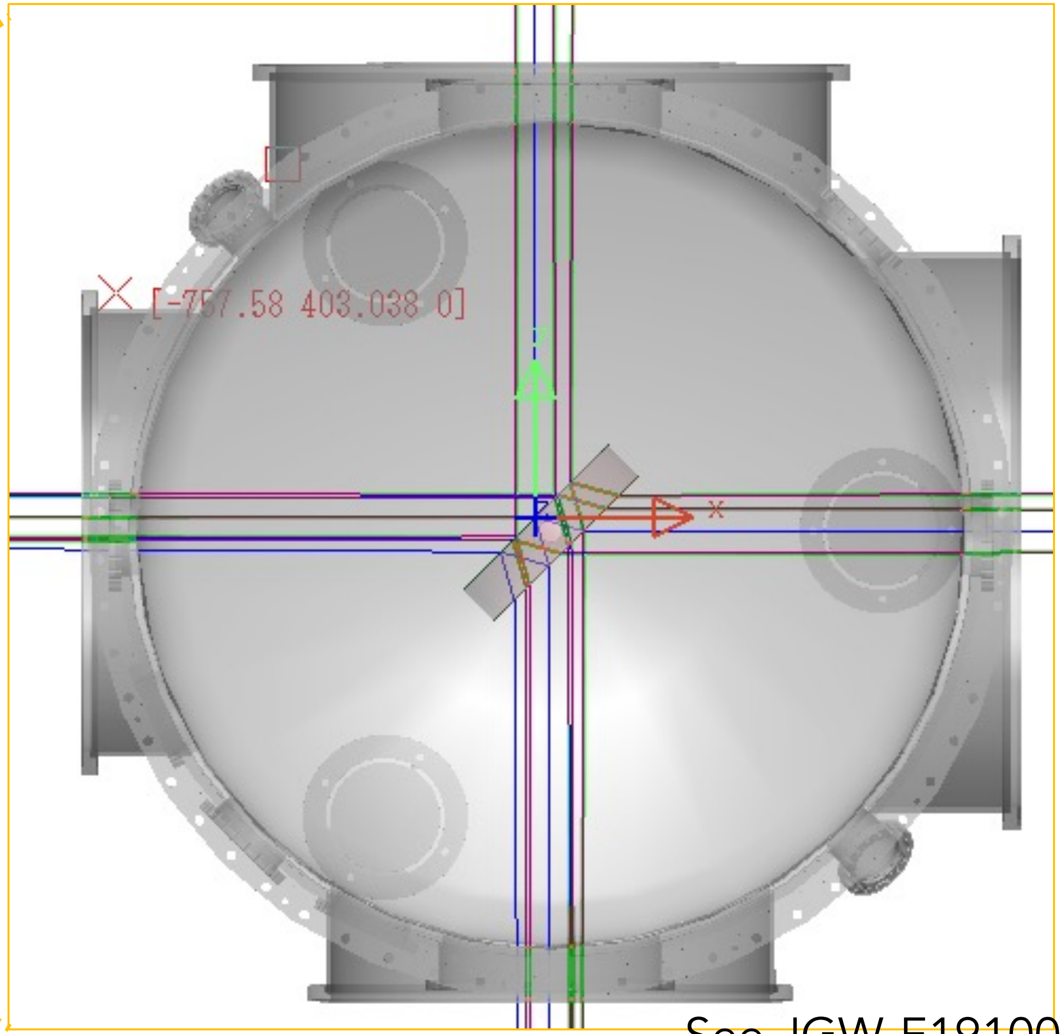


Ghost beams in the center area

- Blue rays: made from a light beam shooting BS from the PR3 side.
- Red rays at PRC: made from a light beam shooting PR3 from the BS side.
- Red rays at SRC: made from a light beam shooting SR3 from the BS side.



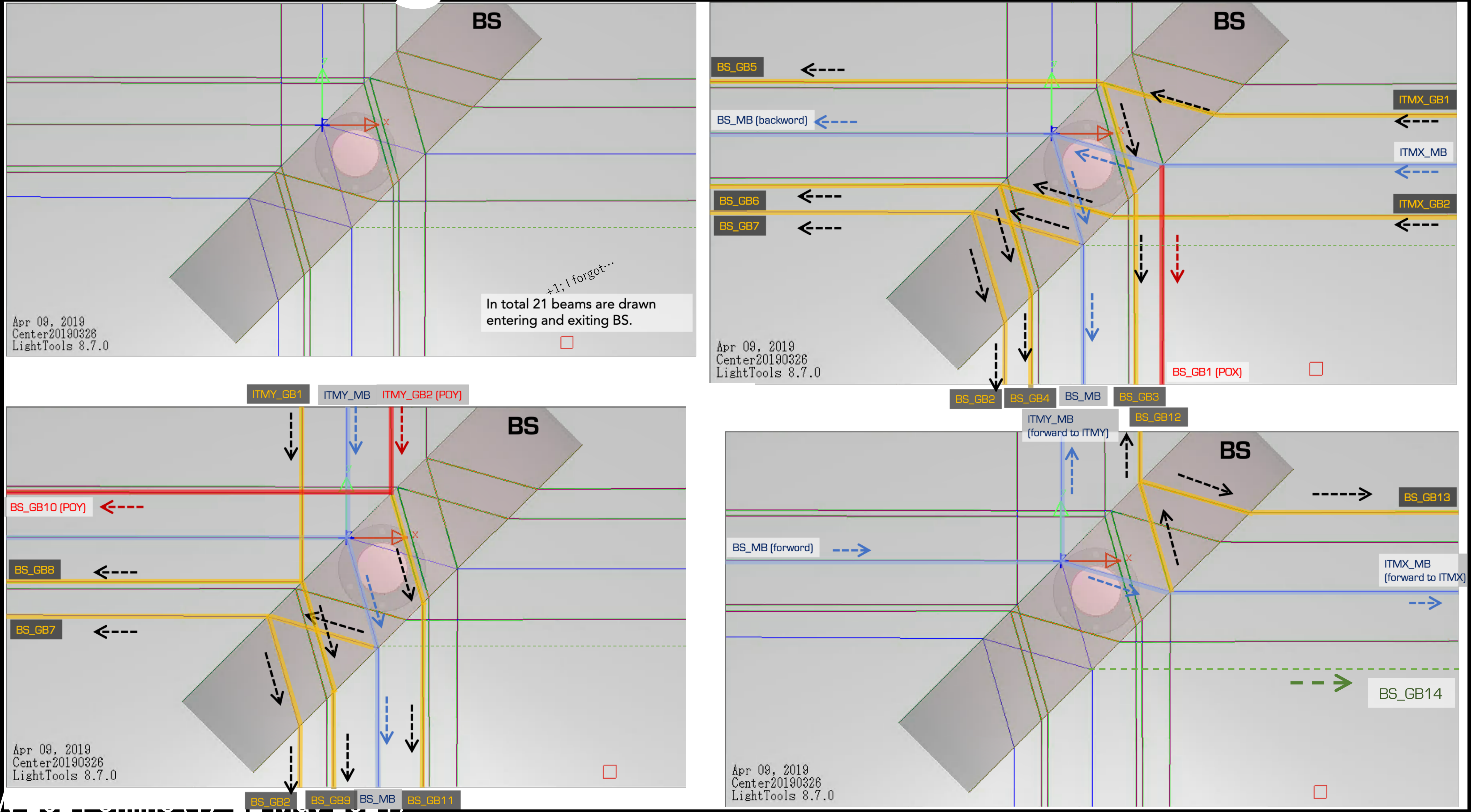
Note: to avoid unnecessary multiple reflections of the ray beams, some virtual absorbers are inserted.

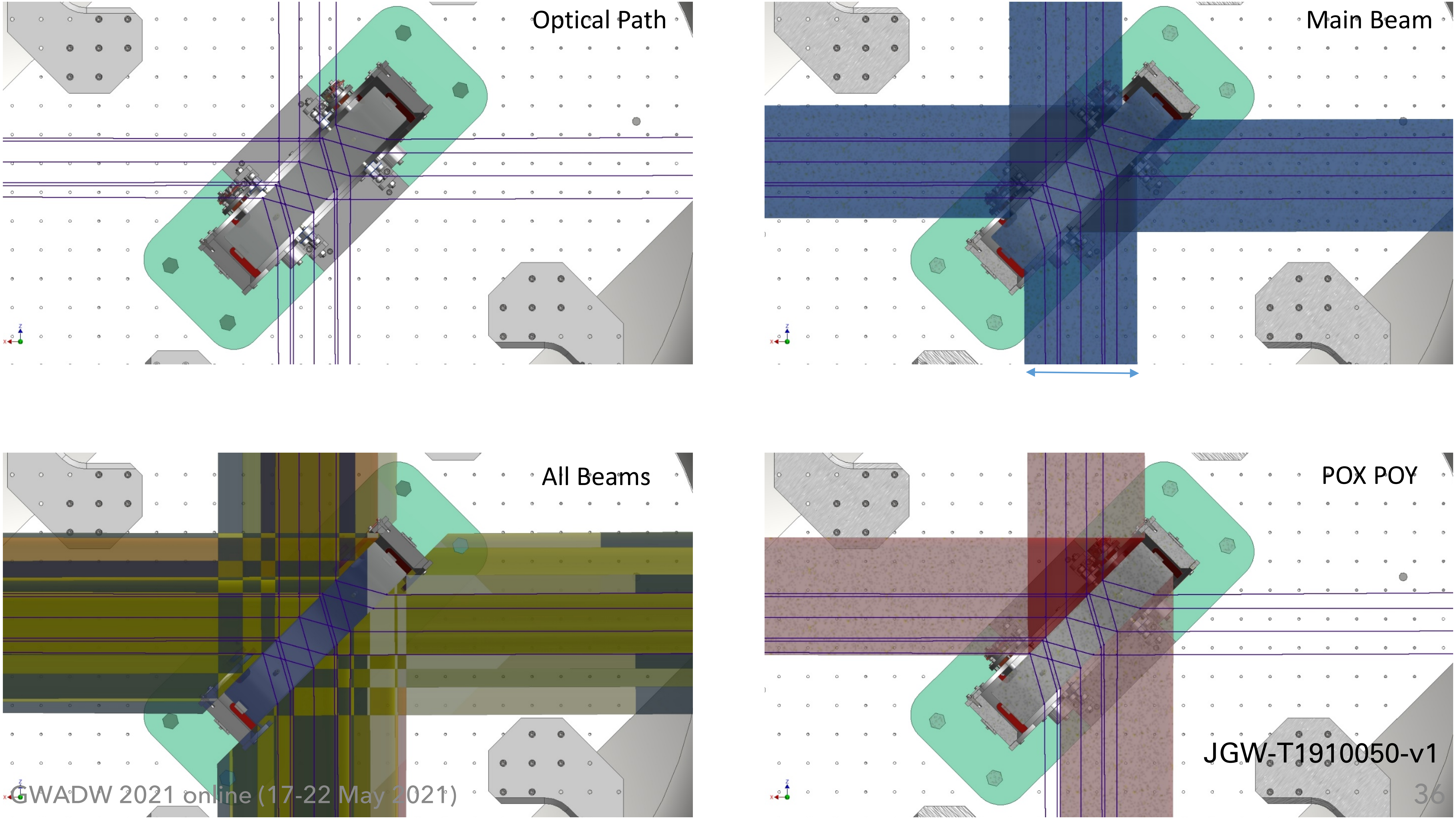


See JGW-E1910040

So much ghost beams…

See JGW-E1910040

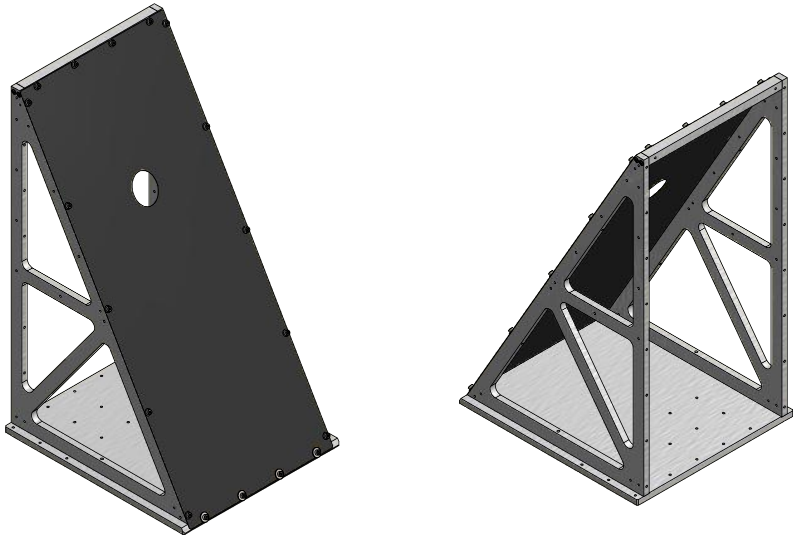



Optical Path
Main Beam
All Beams
POX POY
JGW-T1910050-v1

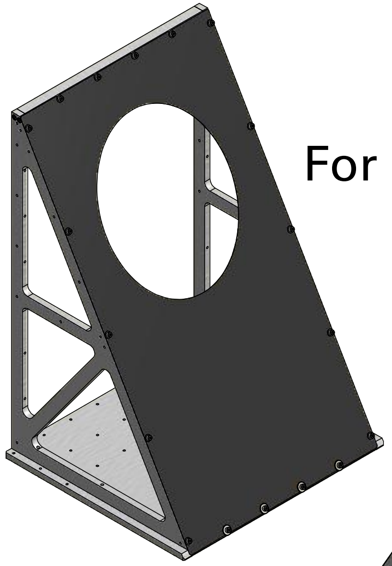
Mid-size baffles

- To catch ghost beams in the center area (BS, PRC, SRC)
- Each a few x 10~100mW

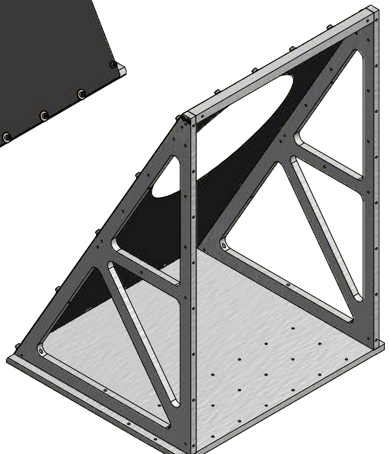
Some examples:



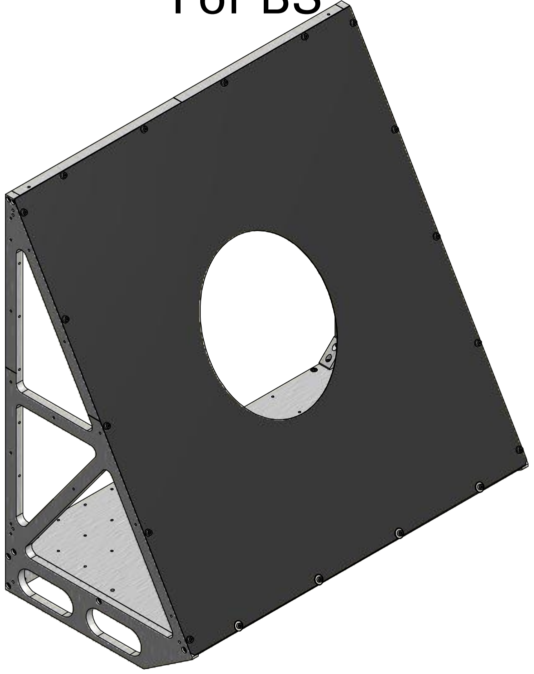
For SR2 HR side



For SR3 HR side



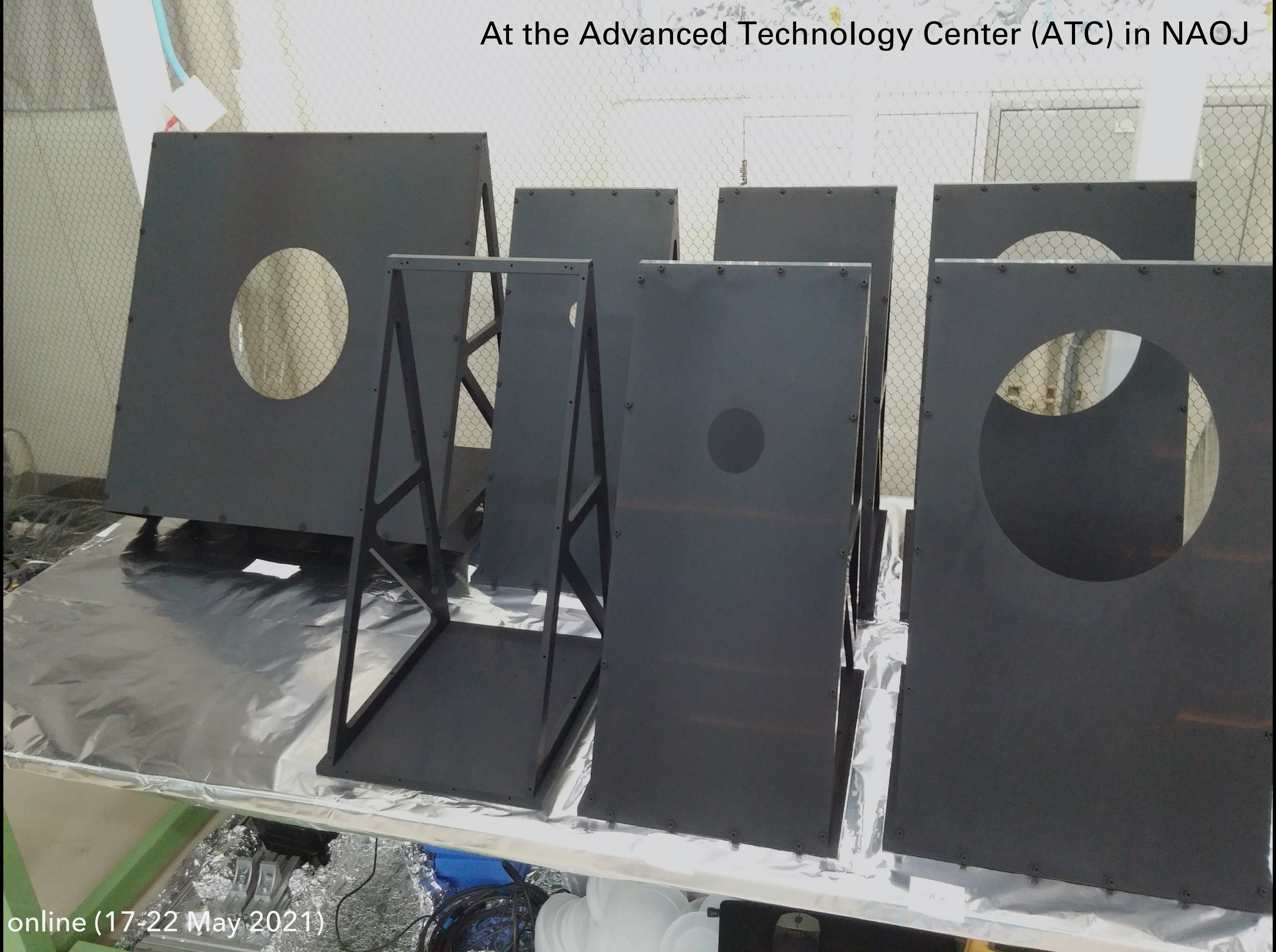
For BS



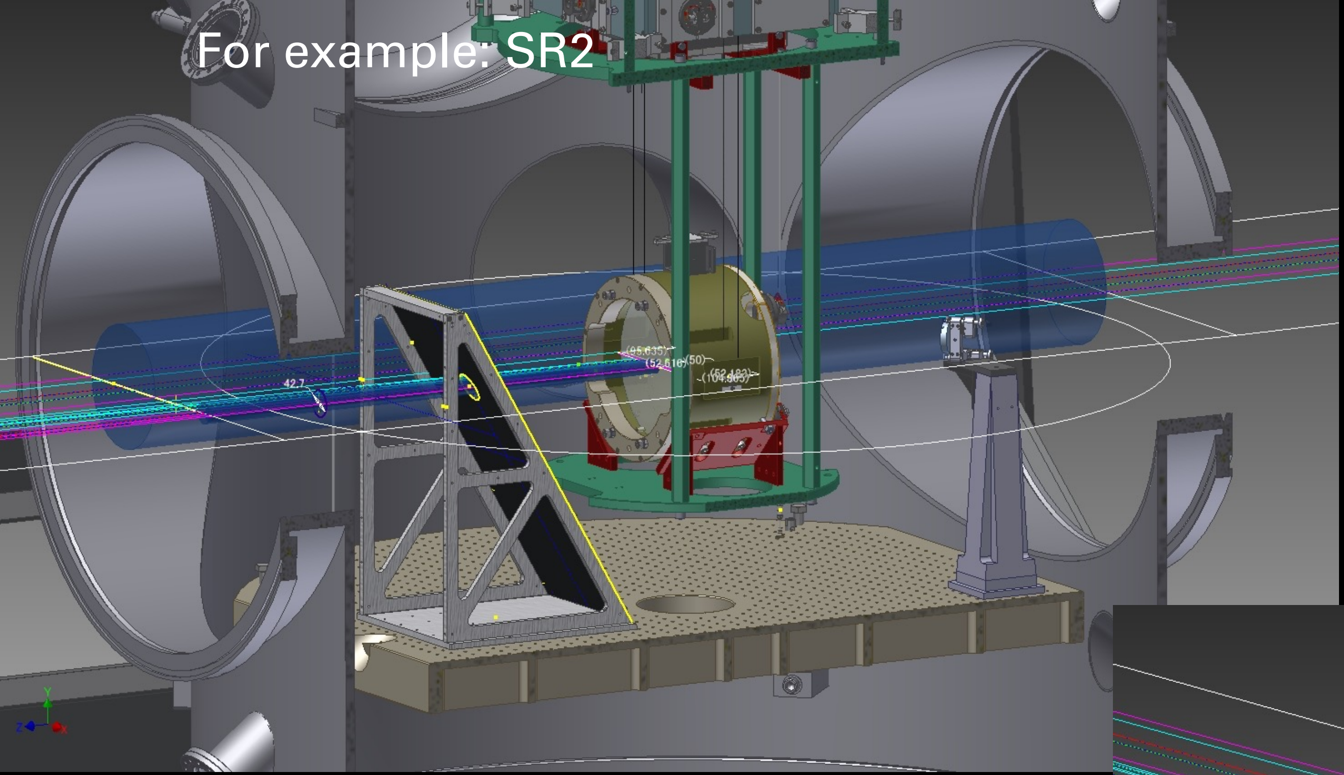
Drawn by N. Hirata

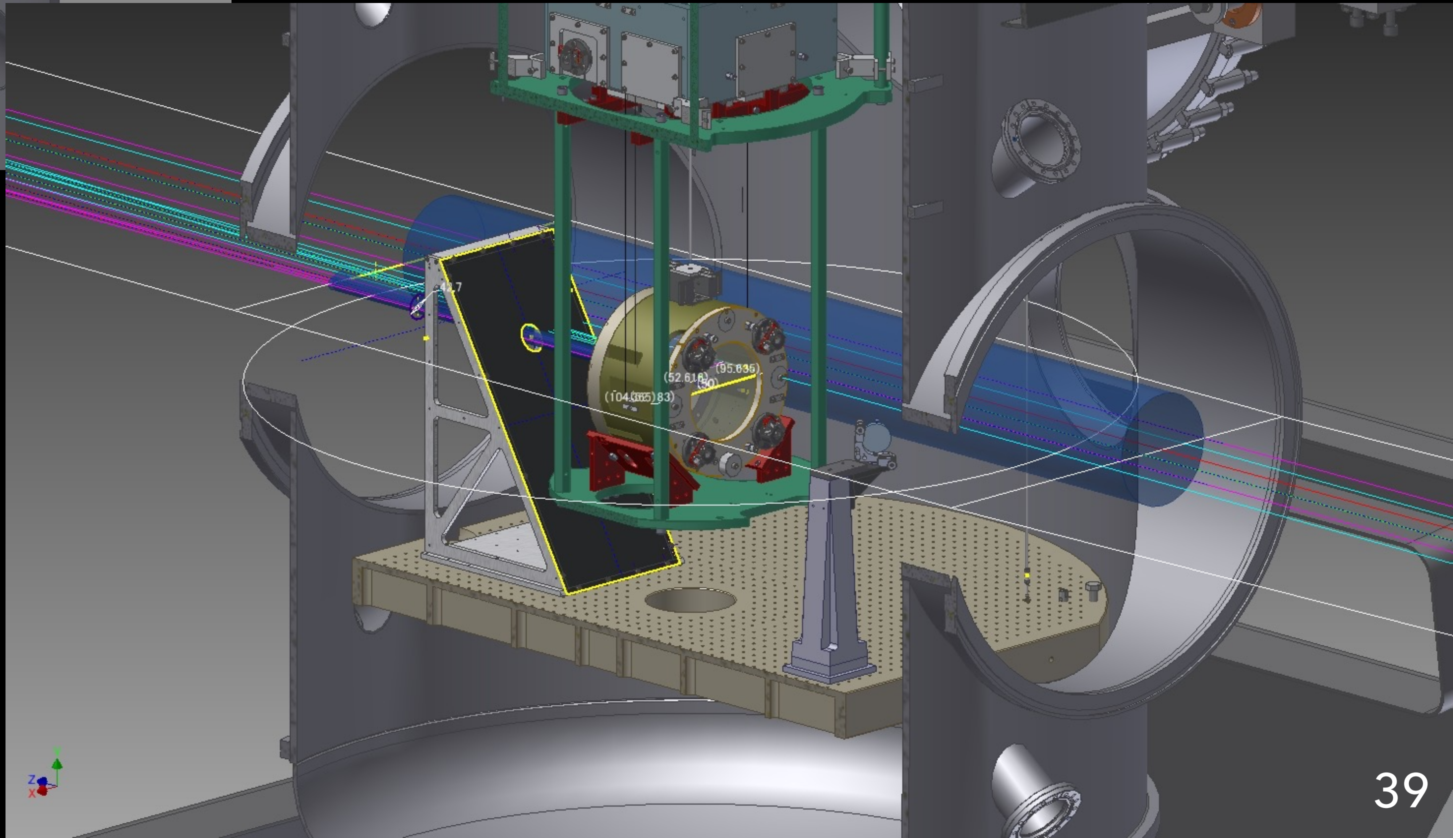
Note that all the sliver-ish parts will be also blackened later.

At the Advanced Technology Center (ATC) in NAOJ



For example: SR2





Summary

11 Mar. 2016 講演者撮影
At the entrance of the KAGRA tunnel

- **GW detector: need to organize many things to reach nice sensitivity.**
- **Auxiliary optics: essential stuffs for KAGRA to reach the final goal.**
- **Let’s detect GWs with the nicer KAGRA!!**